



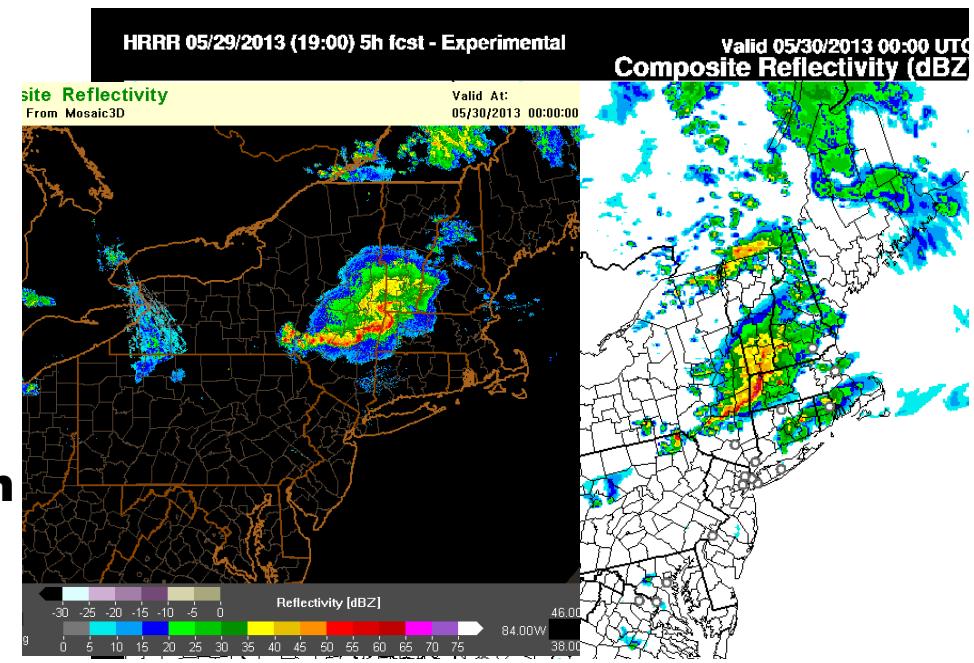
NCEP/EMC, MEG meeting
6 June 2013

Data Assimilation and Model Updates in the 2013 Rapid Refresh (RAP) and High-Resolution Rapid Refresh (HRRR) Analysis and Forecast Systems

Stan Benjamin

NOAA/ESRL/GSD/AMB
**Curtis Alexander, Ming Hu, David
Dowell, Steve Weygandt, Eric
James, Patrick Hofmann, Tanya
Smirnova, John Brown, Joe Olson,
Kevin Brundage, and Brian Jamison**

+ 3 FIM/GFS slides





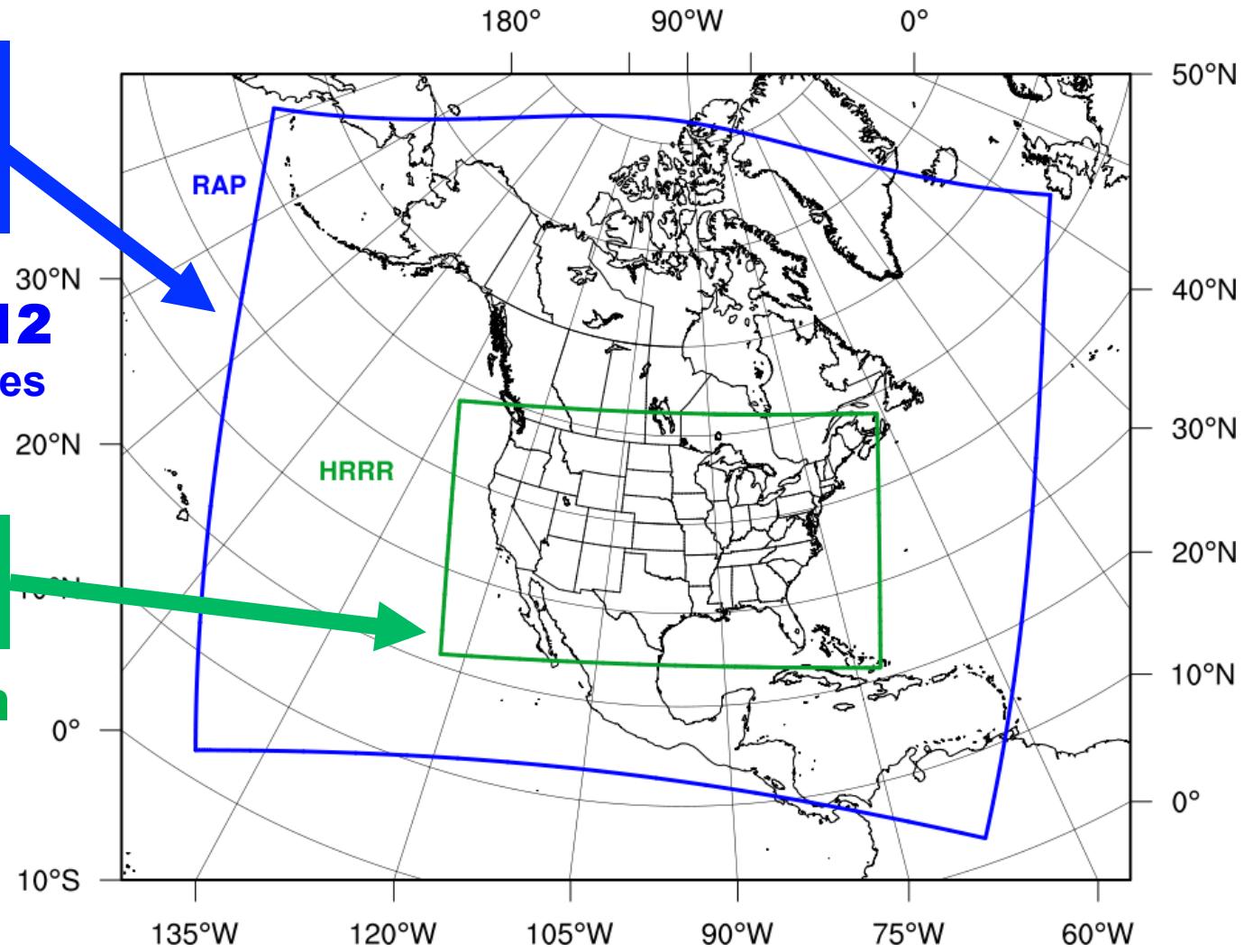
Hourly Updated NWP Models

13km Rapid Refresh (RAP) (mesoscale)

Replaced RUC at NCEP 05/01/12
WRF, GSI, RUC features

3km HRRR (storm-scale)

High-Resolution Rapid Refresh
Experimental 3km nest inside RAP,
hourly 15-h fcst



HRRR-RAP Outline

What has happened since RAPv1 freeze – Dec 2010

- Jan-Mar 2012 changes to HRRR/RAP (@GSD)
 - Highlight: near-surface / radar data assimilation
- Jan-April 2013 changes
 - All now in testing on WCOSS – RAPv2 and HRRR
 - Highlights:
 - 3km/ radar assimilation, ensemble DA
 - Model changes – boundary layer, land-surface
 - Examples of new improvements



RAP and HRRR 2011 Configuration

Model	Run at:	Domain	Grid Points	Grid Spacing	Vertical Levels	Pressure Top	Boundary Conditions	Initialized
RAP	GSD, NCO	North America	758 x 567	13 km	50	10 mb	GFS	Hourly (cycled)
HRRR	GSD	CONUS	1799 x 1059	3 km	50	20 mb	RAP	Hourly - RAP (no-cycle)

Model	Version	Assimilation	Radar DA	Radiation LW/SW	Microphysics	Cumulus Param	PBL	LSM
RAP	WRF-ARW v3.1.1+	GSI 3D-VAR	13-km DFI	RRTM/ Goddard	Thompson v3.3.1	G3 + Shallow	MYJ	RUC 6-lev
HRRR	WRF-ARW V3.1.1+	None: RAP I.C.	None	RRTM/ Dudhia	Thompson v3.1.1	None	MYJ	RUC 6-lev

Model	Horiz/Vert Advection	Scalar Advection	Upper-Level Damping	6 th Order Diffusion	SW Radiation Update	Land Use	MP Tend Limit	Time-Step
RAP	5 th / 3 rd	Monotonic	Diffusive 0.2	none	30 min	Pre-MODIS	0.01 K/s	60 s
HRRR	5 th / 3 rd	Monotonic	Diffusive 0.2	No	30 min	Pre-MODIS	0.1 K/s	18s



RAP and HRRR 2013 Configuration

Model	Run at:	Domain	Grid Points	Grid Spacing	Vertical Levels	Pressure Top	Boundary Conditions	Initialized
RAP	GSD, NCO	North America	758 x 567	13 km	50	10 mb	GFS	Hourly (cycled)
HRRR	GSD	CONUS	1799 x 1059	3 km	50	20 mb	RAP	Hourly – RAP + 3km rad/GSI

Model	Version	Assimilation	Radar DA	Radiation LW/SW	Microphysics	Cumulus Param	PBL	LSM
RAP	WRF-ARW v3.4.1+	GSI Hybrid 3D- VAR/Ensemble	13-km DFI	RRTM/ Goddard	Thompson v3.4.1	G3 + Shallow	MYNN	RUC 9-lev
HRRR	WRF-ARW v3.4.1+	GSI 3D-VAR	3-km 15-min LH	RRTM/ Goddard	Thompson v3.4.1	None	MYNN	RUC 9-lev

Model	Horiz/Vert Advection	Scalar Advection	Upper-Level Damping	6 th Order Diffusion	SW Radiation Update	Land Use	MP Tend Limit	Time-Step
RAP	5 th /5 th	Positive- Definite	w-Rayleigh 0.2	Yes 0.25	10 min	MODIS Fractional	0.01 K/s	60 s
HRRR	5 th /5 th	Positive- Definite	w-Rayleigh 0.2	No	5 min	MODIS Fractional	0.07 K/s	20 s

13km Rapid Refresh and 3km HRRR hourly updated weather models

ESRL – experimental version

NWS-NCEP - operational

- RAPv1 – used in 2011
 - Initialized 2011 HRRR
 - effective but too many storms
- RAPv2 – used in 2012
 - Initialized 2012 HRRR
 - Better use of surface obs / radar,
storm bias eliminated
 - **RAP-2013 – improved radar assim,
GOES cloud assim, ensemble assim**
- HRRR – 2012
 - Major improvement over 2011 HRRR,
storm coverage/accuracy
- **HRRR – 2013** 
 - **3km/15min radar assimilation**
 - **Initialized from RAP-2013**
 - **Available 45 min earlier, much more
accurate 0-15h storm forecasts,
more reliable 2-computer**
- Implemented 1 May 2012
- RAPv2 - Scheduled to be implemented in fall 2013
- HRRR – estimated early 2014



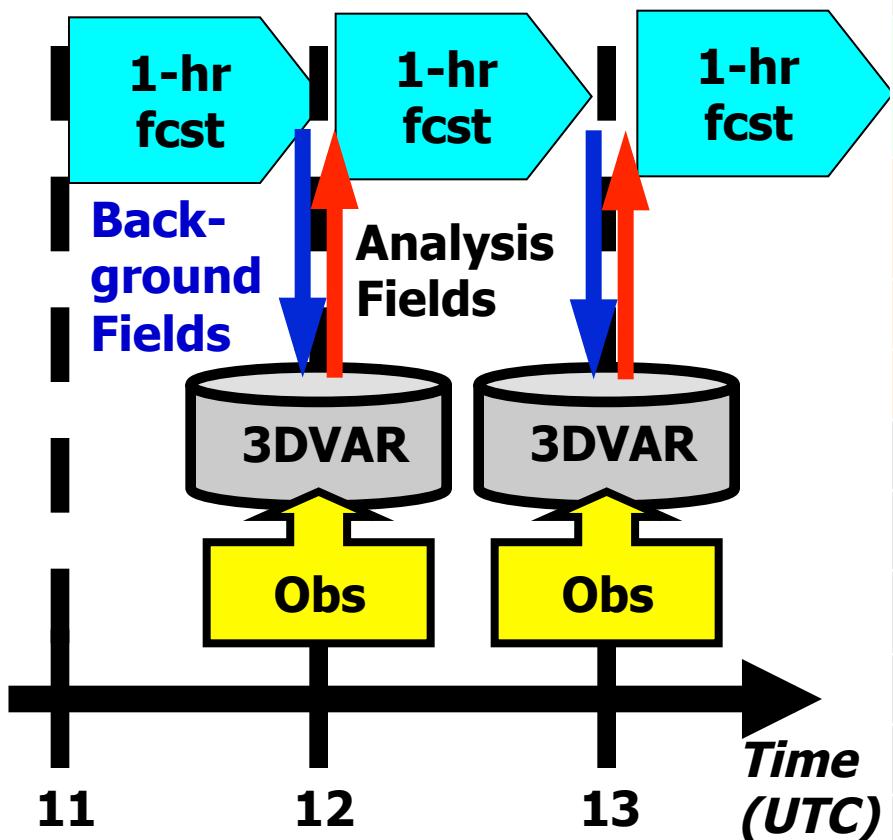
Rapid Refresh

Hourly Update Cycle

Partial cycle atmospheric fields – introduce GFS information 2x/day

Cycle hydrometeors

**Fully cycle all land-sfc fields
(soil temp, moisture, snow)**

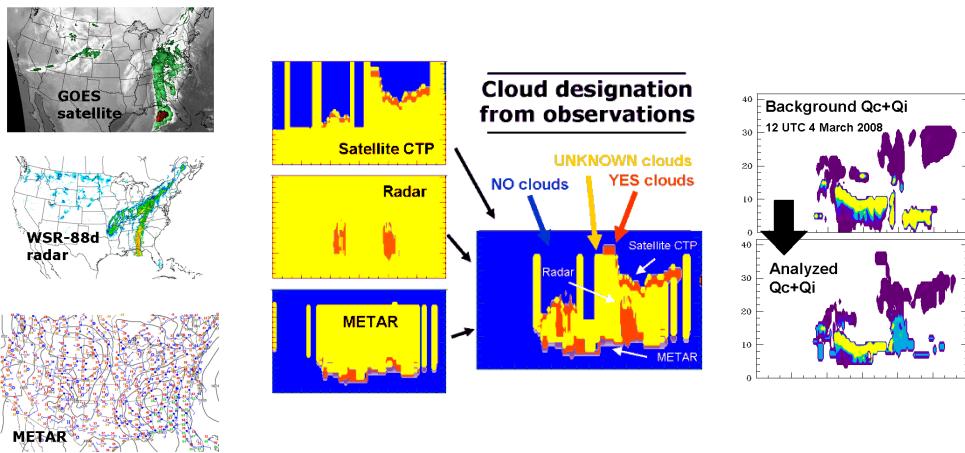


Hourly Observations	RAP 2013 N. Amer
Rawinsonde (T,V,RH)	120
Profiler – NOAA Network (V)	21
Profiler – 915 MHz (V, Tv)	25
Radar – VAD (V)	125
Radar reflectivity - CONUS	1km
Lightning (proxy reflectivity)	NLDN, GLD360
Aircraft (V,T)	2-15K
Aircraft - WVSS (RH)	0-800
Surface/METAR (T,Td,V,ps,cloud, vis, wx)	2200- 2500
Buoys/ships (V, ps)	200-400
Mesonet (T, Td, V, ps)	flagged
GOES AMVs (V)	2000- 4000
AMSU/HIRS/MHS radiances	Used
GOES cloud-top press/temp	13km
GPS – Precipitable water	260
WindSat scatterometer	2-10K
Nacelle/Tower/Sodar	20/100/10

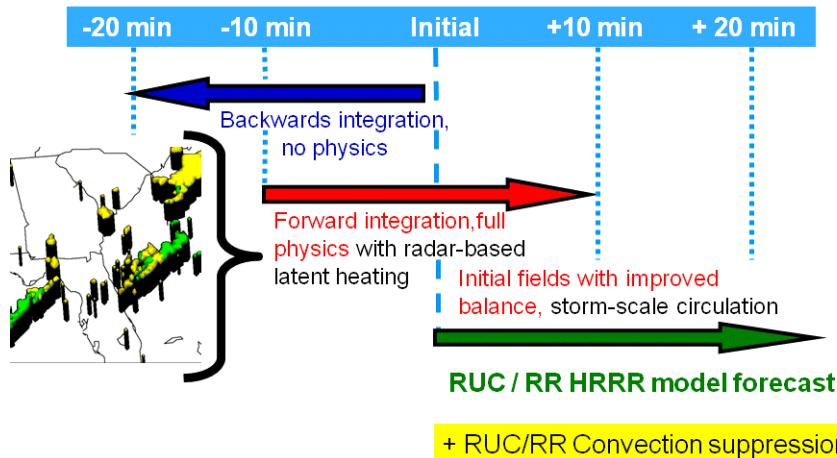


Rapid Refresh Specific Analysis Features

Cloud and hydrometeor analysis



Digital filter-based reflectivity assimilation (DDFI)



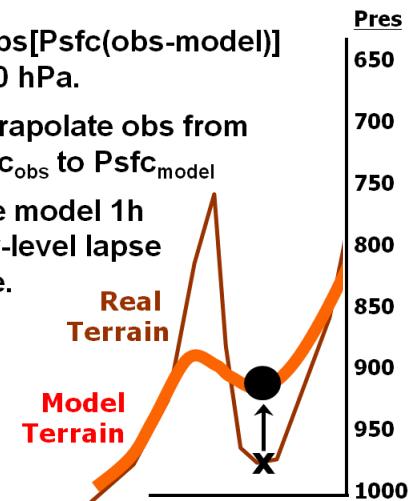
Special treatments for surface observations

Elevation correction

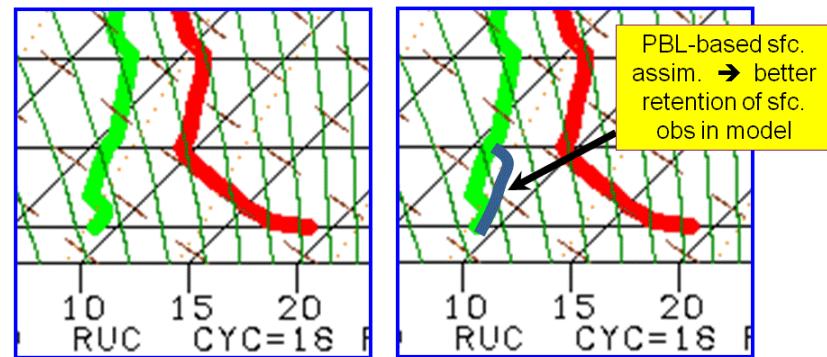
If $\text{abs}[\text{Psfc}(\text{obs-model})] < 70 \text{ hPa}$.

Extrapolate obs from Psfc_{obs} to $\text{Psfc}_{\text{model}}$

Use model 1h low-level lapse rate.

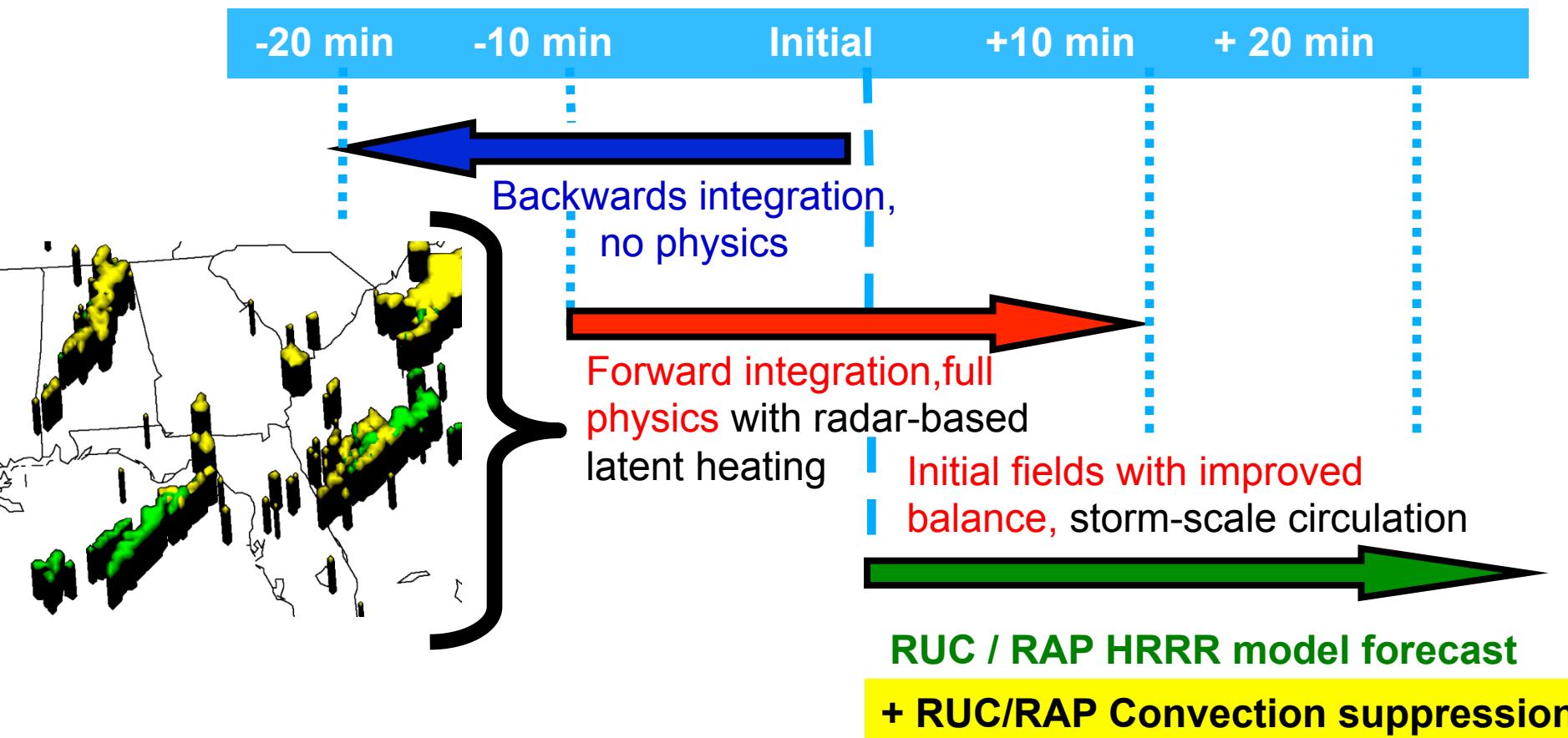


PBL-based pseudo-observations

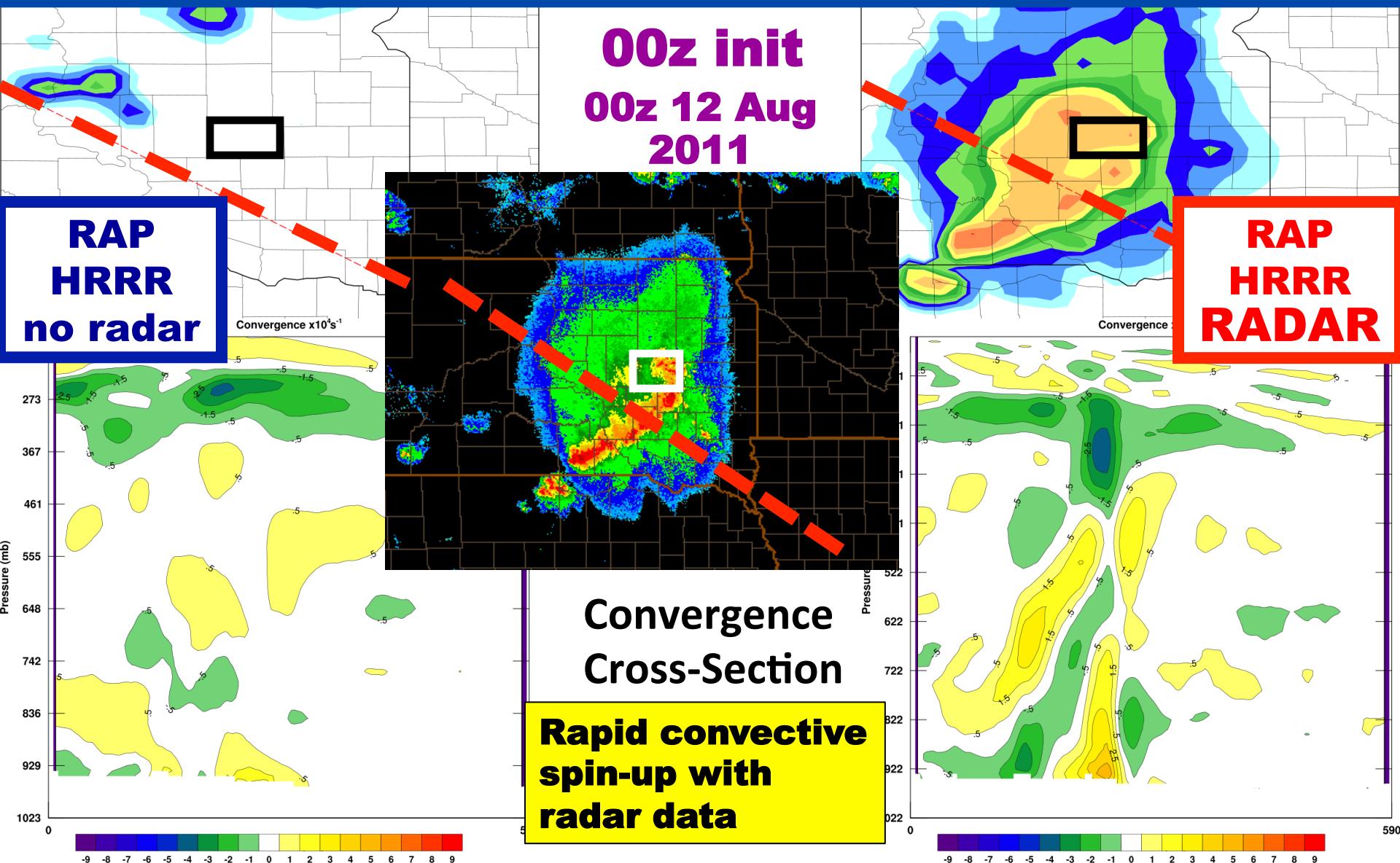


RAP Radar Reflectivity Assimilation

Digital filter-based reflectivity assimilation initializes ongoing precipitation regions

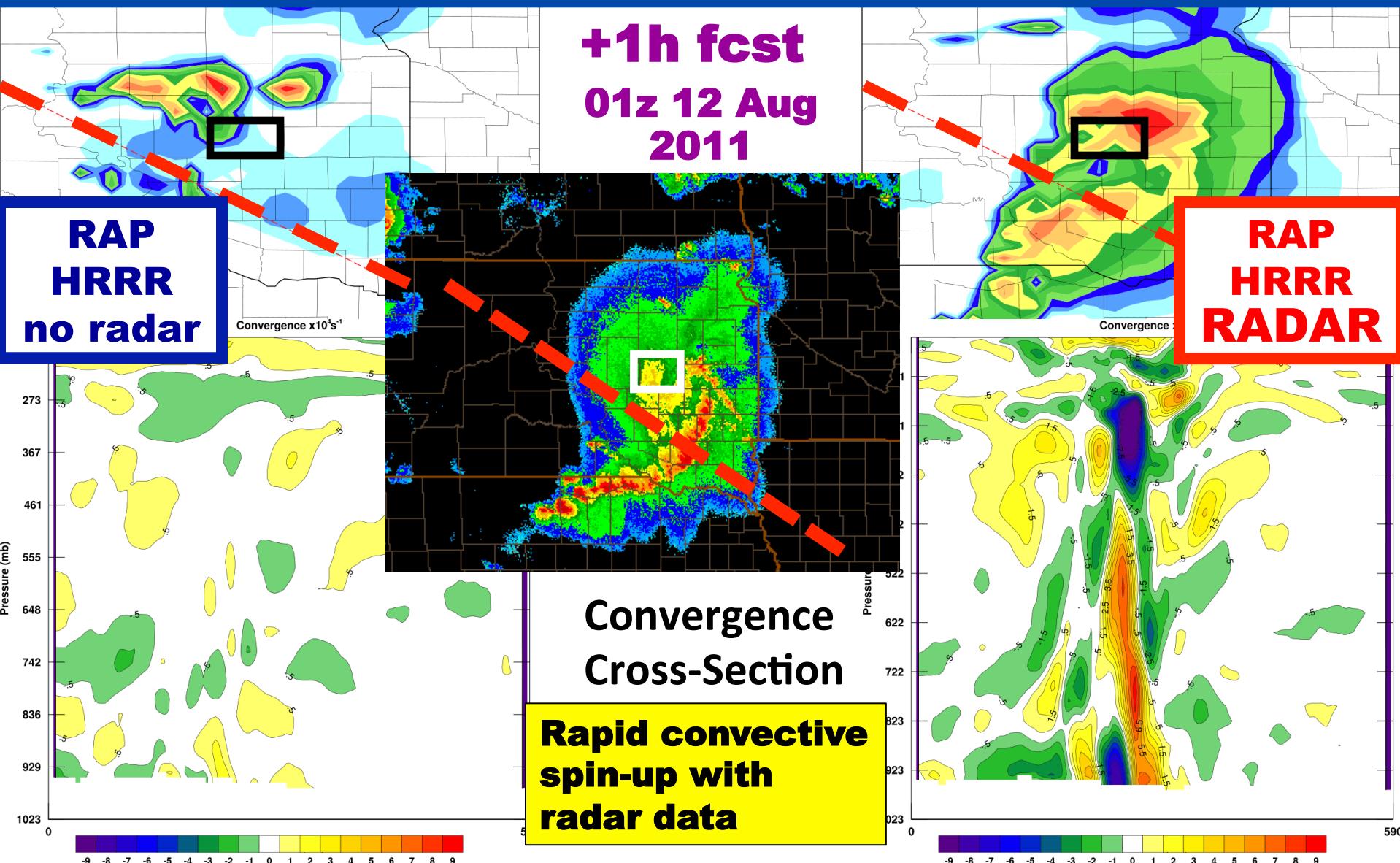


Radar Reflectivity Assimilation



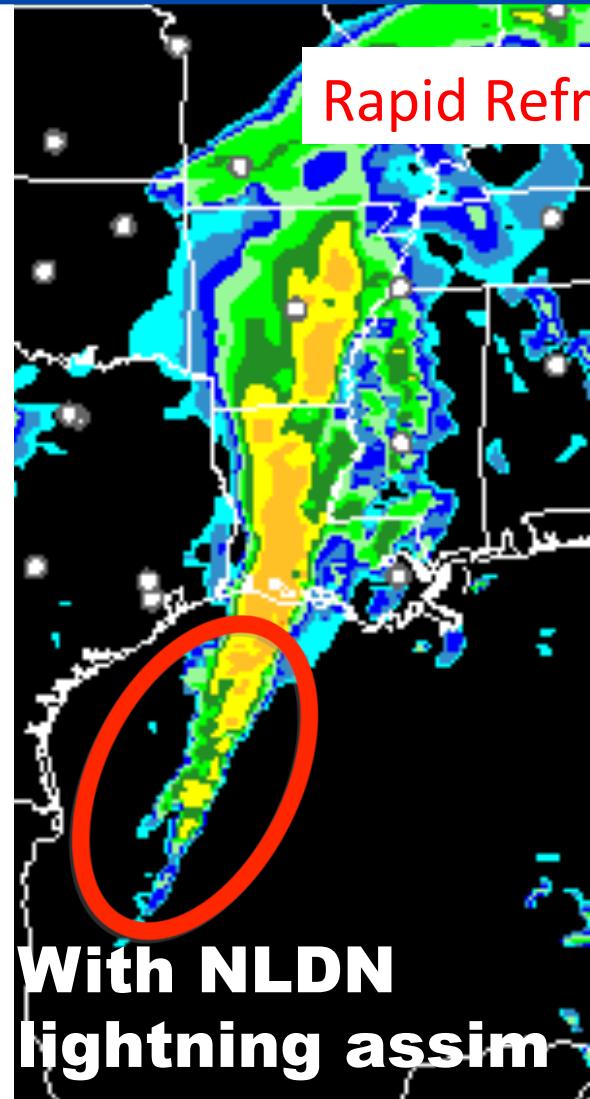


Radar Reflectivity Assimilation

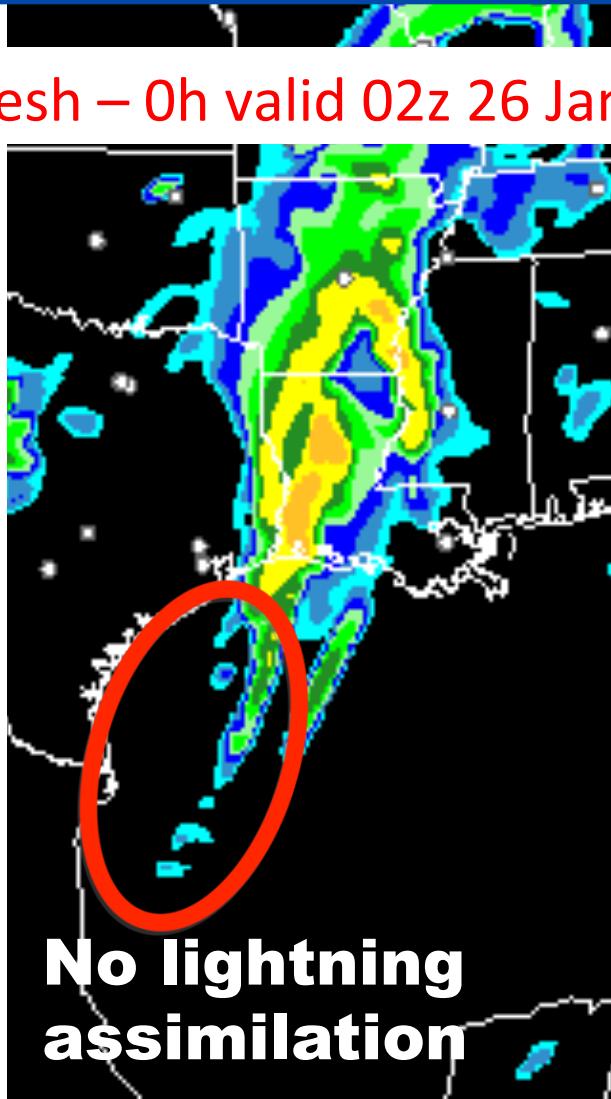




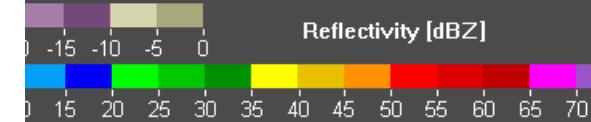
RAP Lightning Assimilation



Rapid Refresh – 0h valid 02z 26 Jan 2012



**Observed
Reflectivity**



Improved convective coverage off the coast with lightning assimilation



RAP/HRRR Changes (from 2011→2012)

	Model	Data Assimilation
RAP-ESRL (13 km)	<p>WRFv3.3.1+</p> <p>Numerics changes: (w-damp upper bound conditions, 5th-order vertical advection)</p> <p>Physics changes: (microphysics, land-surface, PBL)</p> <p>MODIS land use, fractional 30→05 min shortwave radiation</p> <p>New reflectivity diagnostic</p>	<p>GSI merge with trunk</p> <p>Soil moisture/temp adjustment</p> <p>Temp-dependent radar-hydrometeor building</p> <p>GPS-precip water assim mods</p> <p>Cloud assim mods</p> <p>Tower/nacelle/sodar observations</p> <p>GLD360 lightning</p>
HRRR (3 km)	<p>WRFv3.3.1+</p> <p>Numerics changes: (w-damp upper bound conditions, 5th-order vertical advection)</p> <p>Physics changes: (microphysics, land-surface, PBL)</p> <p>MODIS land use, fractional 30→05 min shortwave radiation</p> <p>New reflectivity diagnostic</p>	<p>Changes with high/medium importance for overall forecast skill</p>



HRRR/RAPv2 changes for spring 2013

	Model	Data Assimilation
RAP-ESRL (13 km)	<p>WRFv3.4.1+ incl. physics changes (incl. snow-radiation fix)</p> <p><u>Physics changes:</u></p> <p>MYNN PBL scheme –Olson version 9-layer RUC LSM (from 6-layer) Modified roughness length Thompson microphysics update</p> <p>Changes with high/medium importance for <i>overall</i> forecast skill</p>	<p>Merge with GFS trunk GFS ensemble background error cov Stronger/symmetric soil adjustment, adapted for 9-layer LSM Radar hydrometeor building/clearing Snow cover building (added) /modified trimming (no low-level temp limit) Fractional cloud assimilation</p>
HRRR (3 km)	<p>WRFv3.4.1+ incl. physics changes (incl. snow-radiation fix)</p> <p><u>Physics changes:</u></p> <p>MYNN PBL scheme -Olson version 9-layer RUC LSM (from 6-layer) Modified roughness length Thompson microphysics update</p>	<p>3 km/15 min radar reflectivity assimilation 3km GSI full-data assimilation for last pass, including 3km cloud/hydrometeor assimilation</p> <p>30-45 min reduction in latency</p>



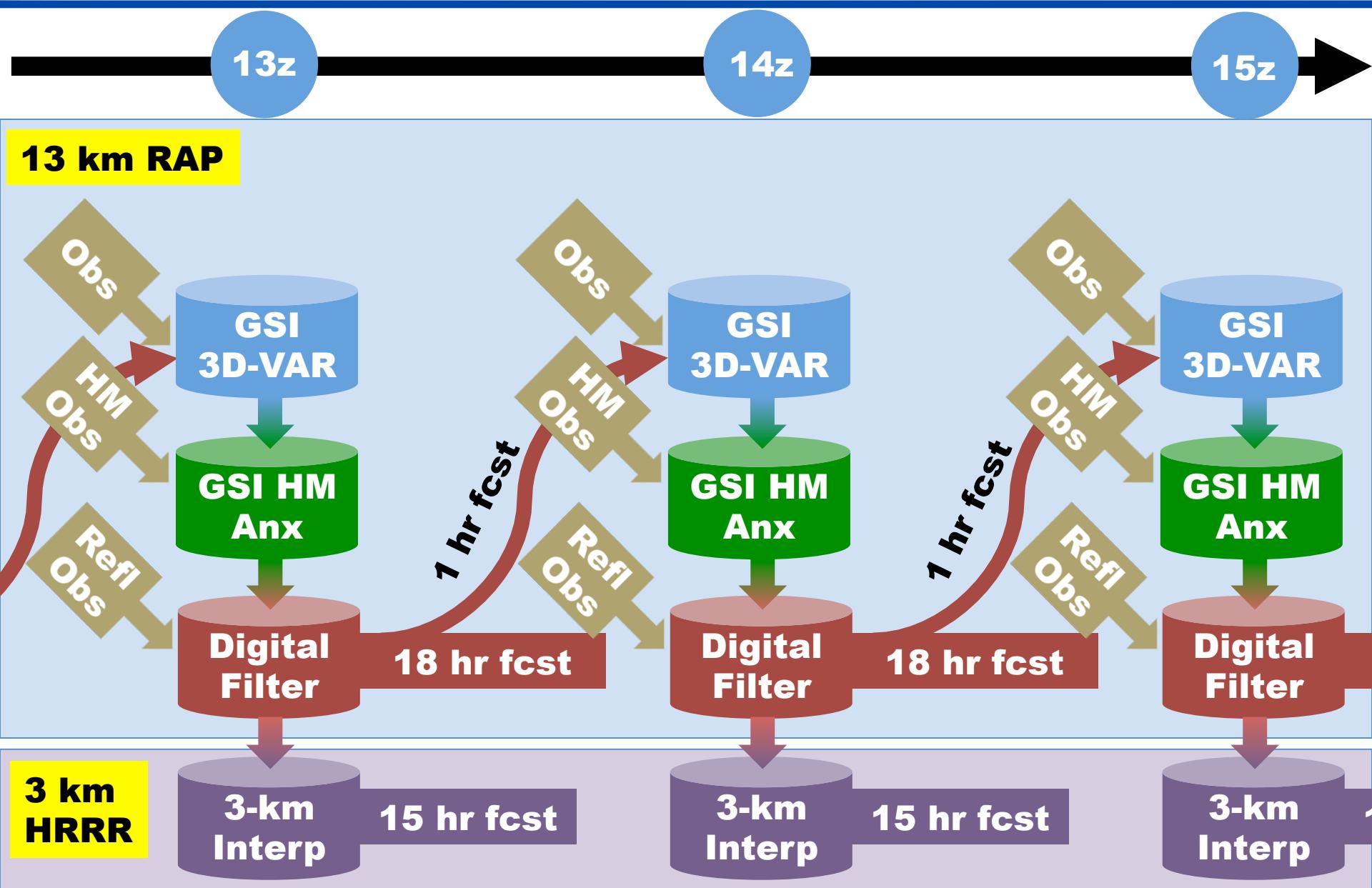
RAP and HRRR 2013 Configuration

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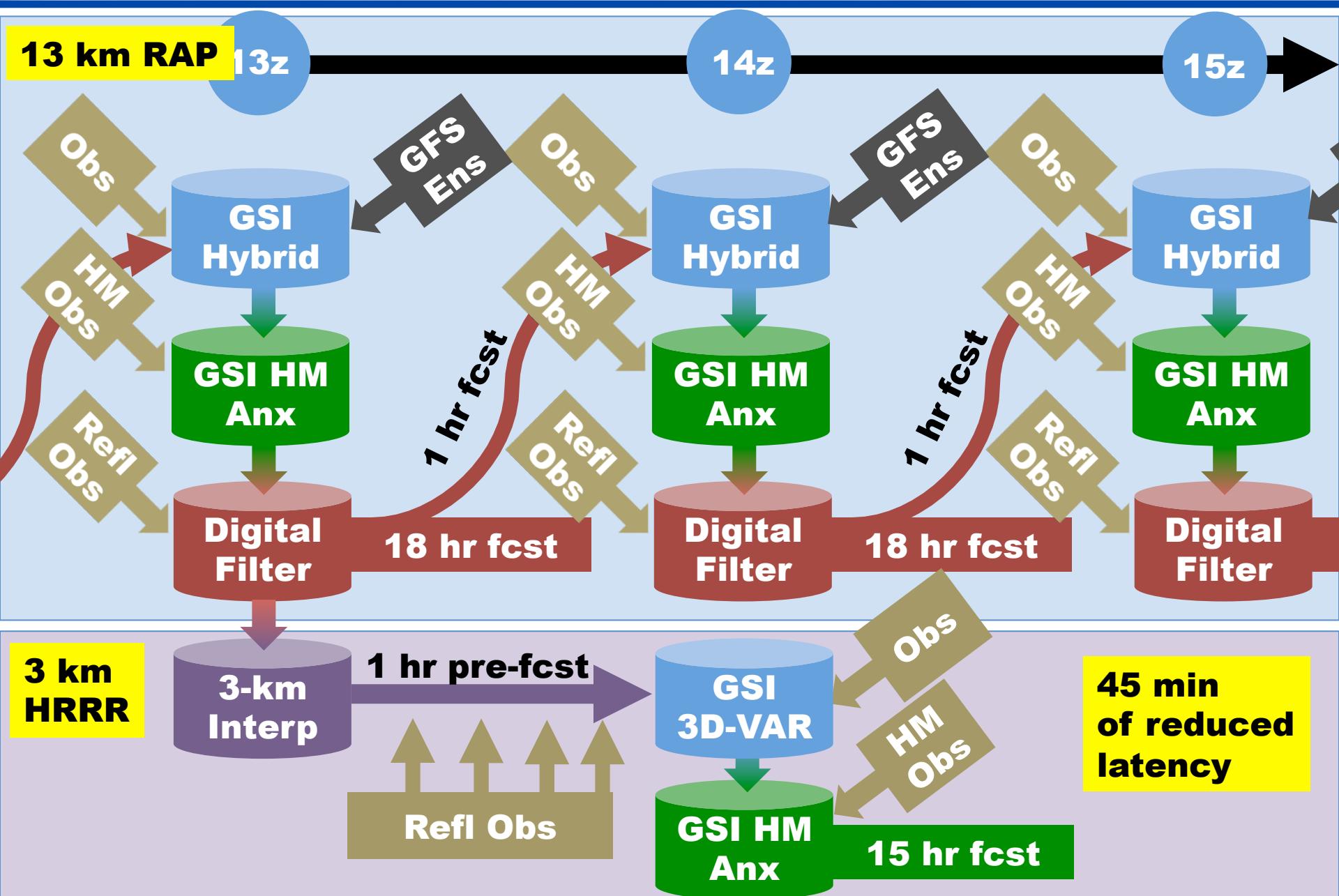
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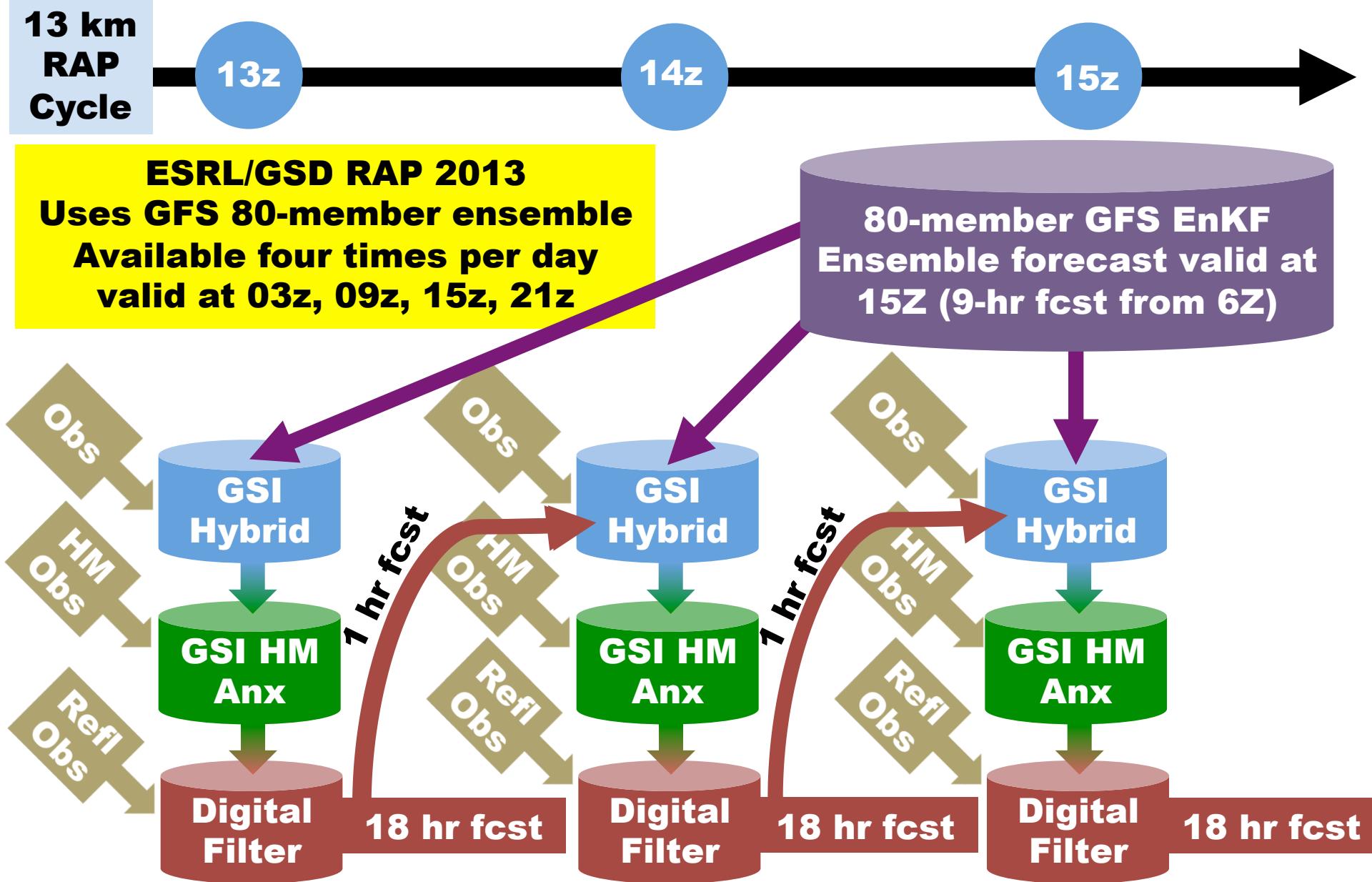
2012 HRRR Initialization from RAP



2013 HRRR Initialization from RAP



ESRL RAP 2013 Data Assimilation



ESRL RAP 2013 Data Assimilation

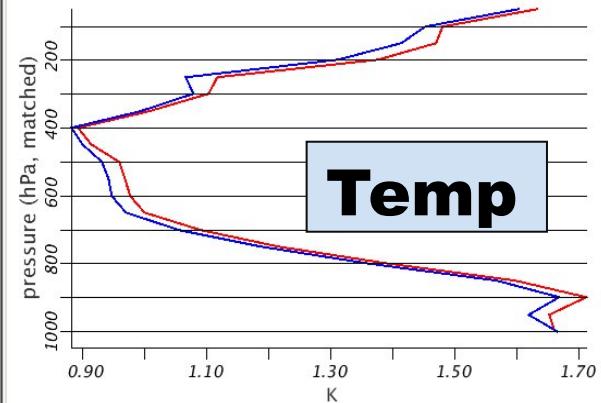
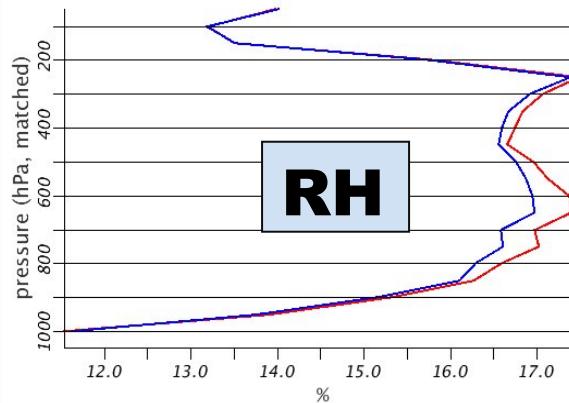
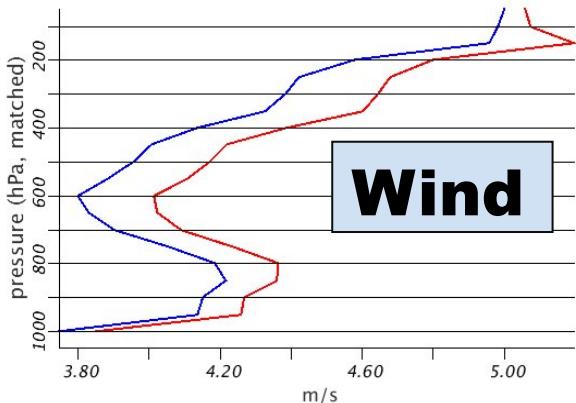
RMSE Vertical Profiles: Soundings from 1000-100 mb

22 Nov – 22 Dec 2012

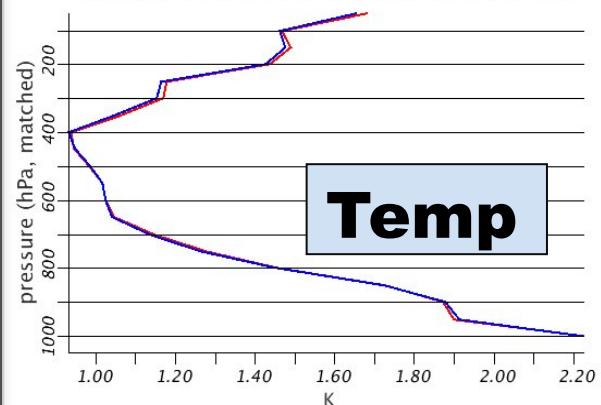
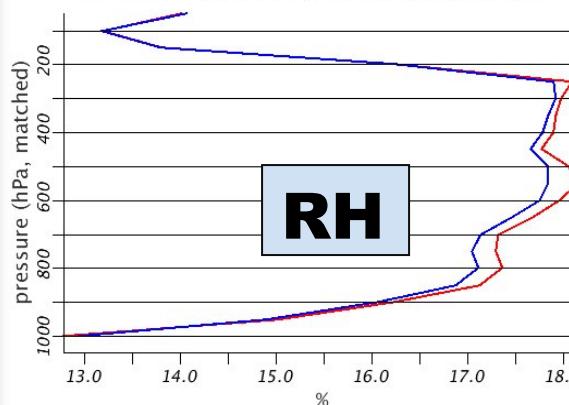
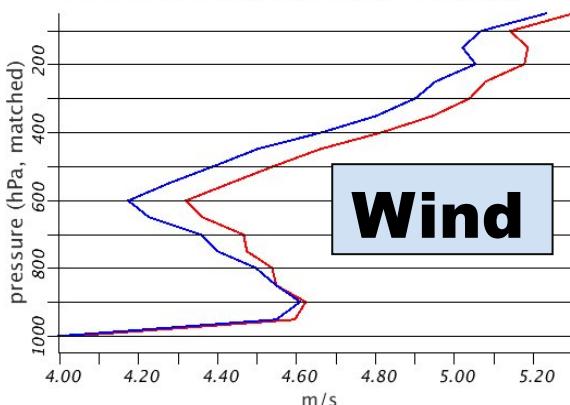
RAP Hybrid

RAP No Hybrid (3D-VAR)

03-hr Forecast



12-hr Forecast

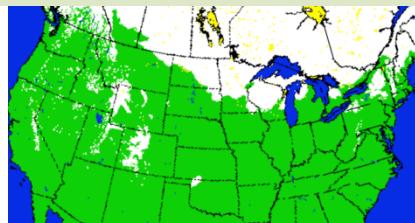


Improved upper-air environment

ESRL RAP 2013 Data Assimilation

Surface Snow Water Equivalent Valid 00z 05 April 2013

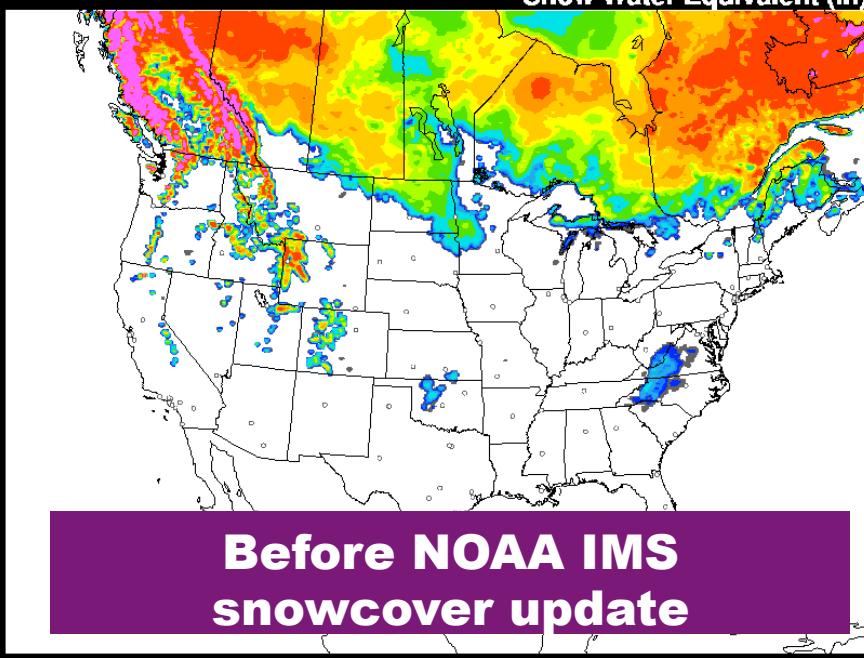
**GSI Snow
Cover Analysis
(Run 00z Daily)**



**Using Interactive Multisensor
Snow/Ice Mapping System
(IMS)**

RAP-primary-ESRL 04/04/2013 (23:00) 1 hr fcst

Valid 04/05/2013 00:00 UTC
Snow Water Equivalent (in)

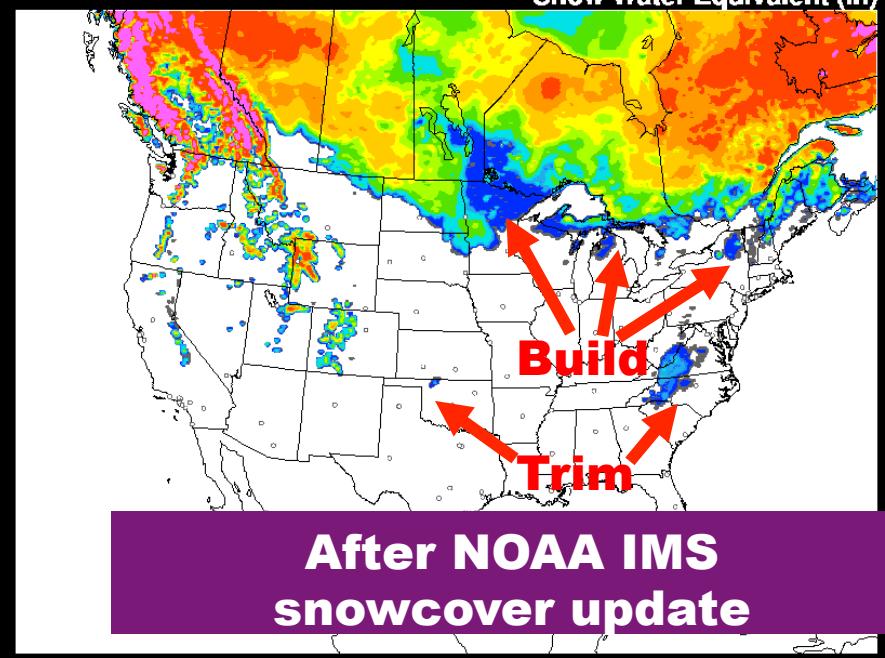


**Before NOAA IMS
snowcover update**

.01 .1 .3 .5 1 2 3 4 5 7.5 10 20

RAP-primary-ESRL 04/05/2013 (00:00) 0 hr fcst

Valid 04/05/2013 00:00 UTC
Snow Water Equivalent (in)



**After NOAA IMS
snowcover update**

.01 .1 .3 .5 1 2 3 4 5 7.5 10 20

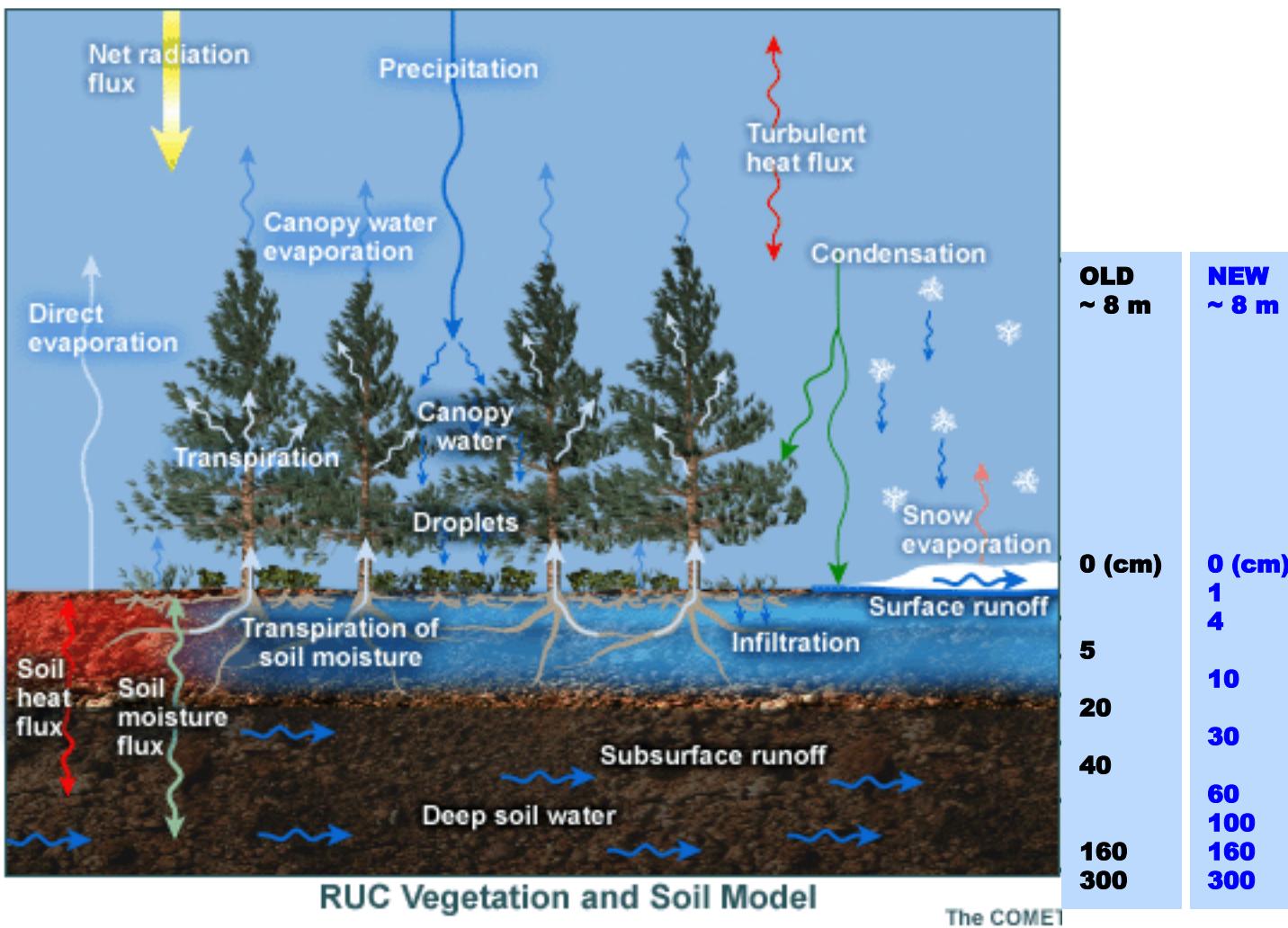
Improved snowcover



RAP/HRRR 2013 Model Update

RUC Land Surface Model (LSM) increased from 6 to 9 levels

Changed PBL scheme from MYJ (Mellor-Yamada-Janjic) to MYNN (Mellor-Yamada-Nakanishi-Niino)
Increased surface roughness lengths



Thinner soil layer in the energy and moisture budgets – potential for increased diurnal cycle near surface: reduced warm bias at night and cold bias during the day

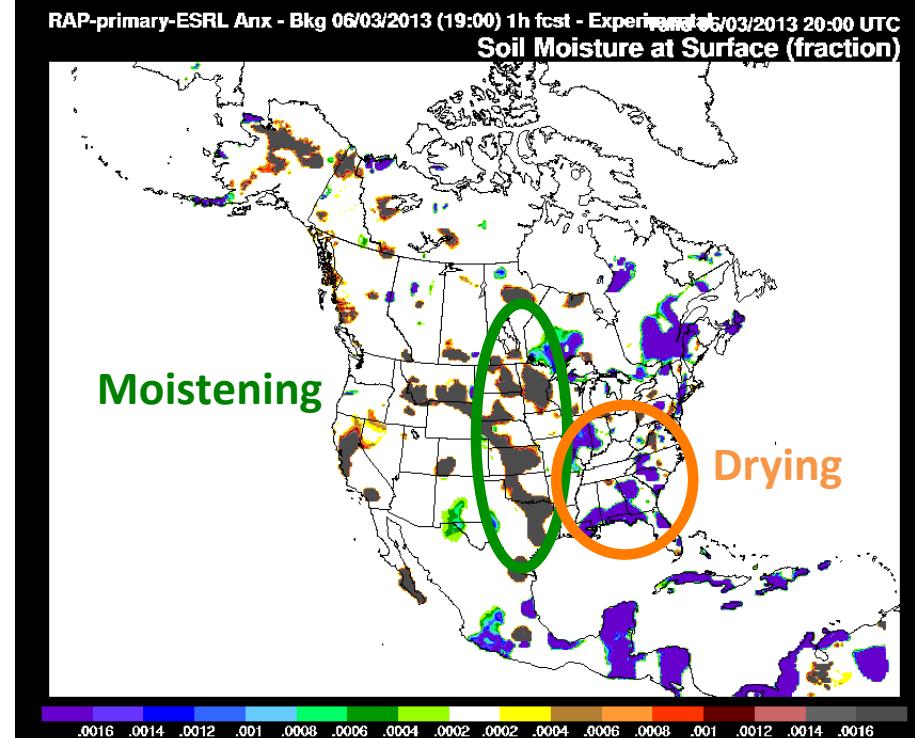
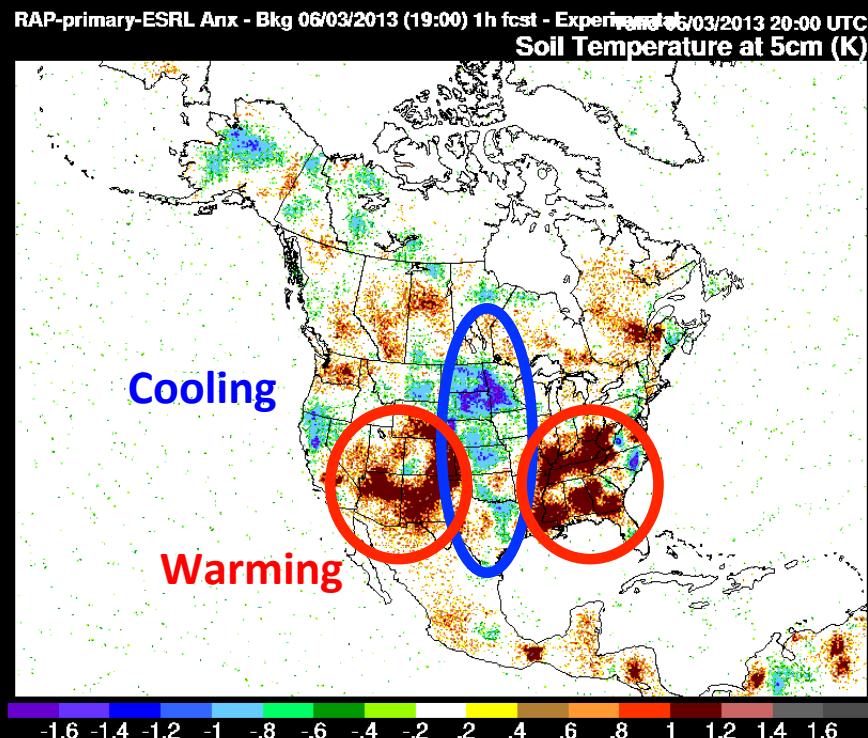


Soil Adjustment (GSI)

Soil Temperature

**Valid
20 UTC
03 June 2013**

Soil Moisture



Based upon surface temperature and dewpoint innovations

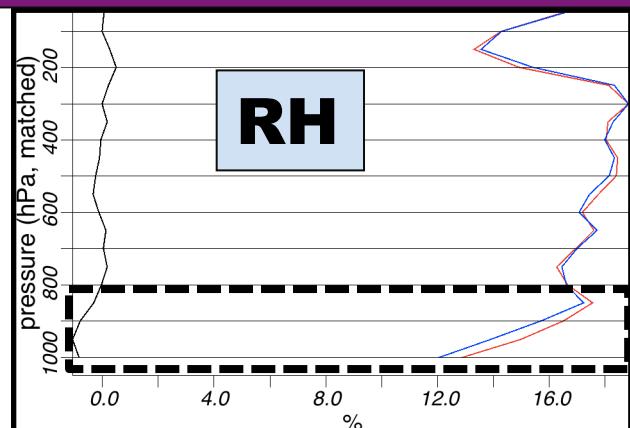
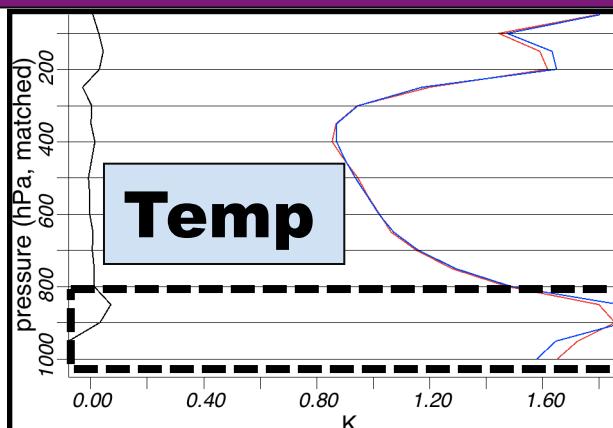
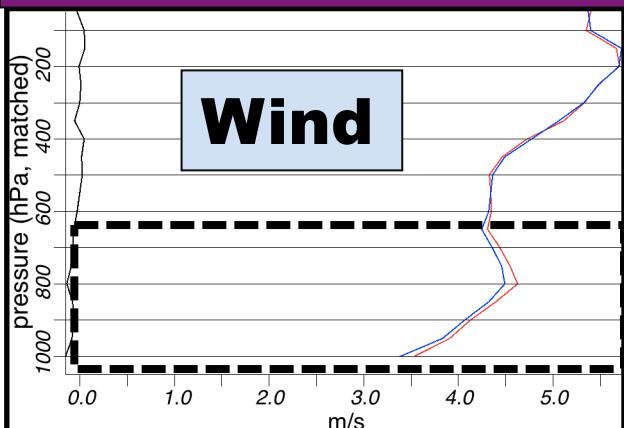


RAP/HRRR 2013 Model Update

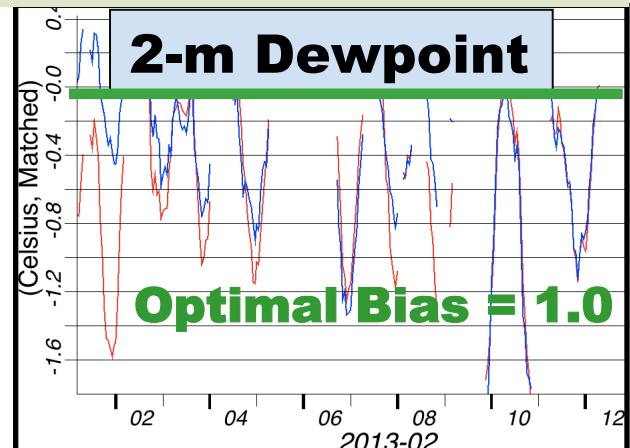
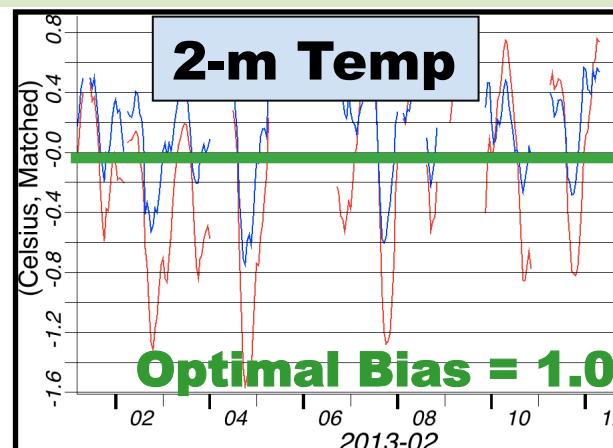
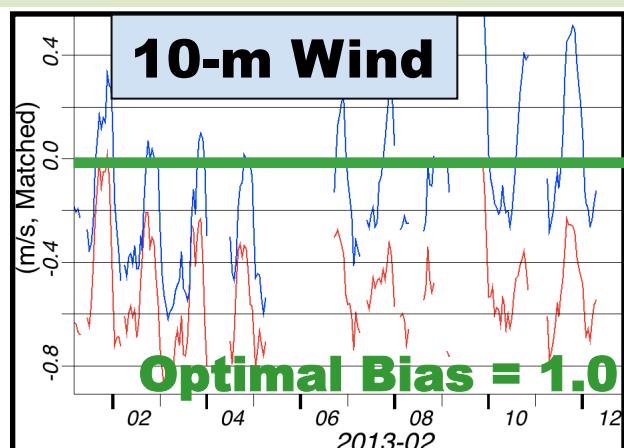
RMSE Vertical Profiles: Soundings 14 Jan – 11 Feb 2013

— MYNN, 9-level RUC LSM — MYJ, 6-level RUC LSM

06-hr Forecast



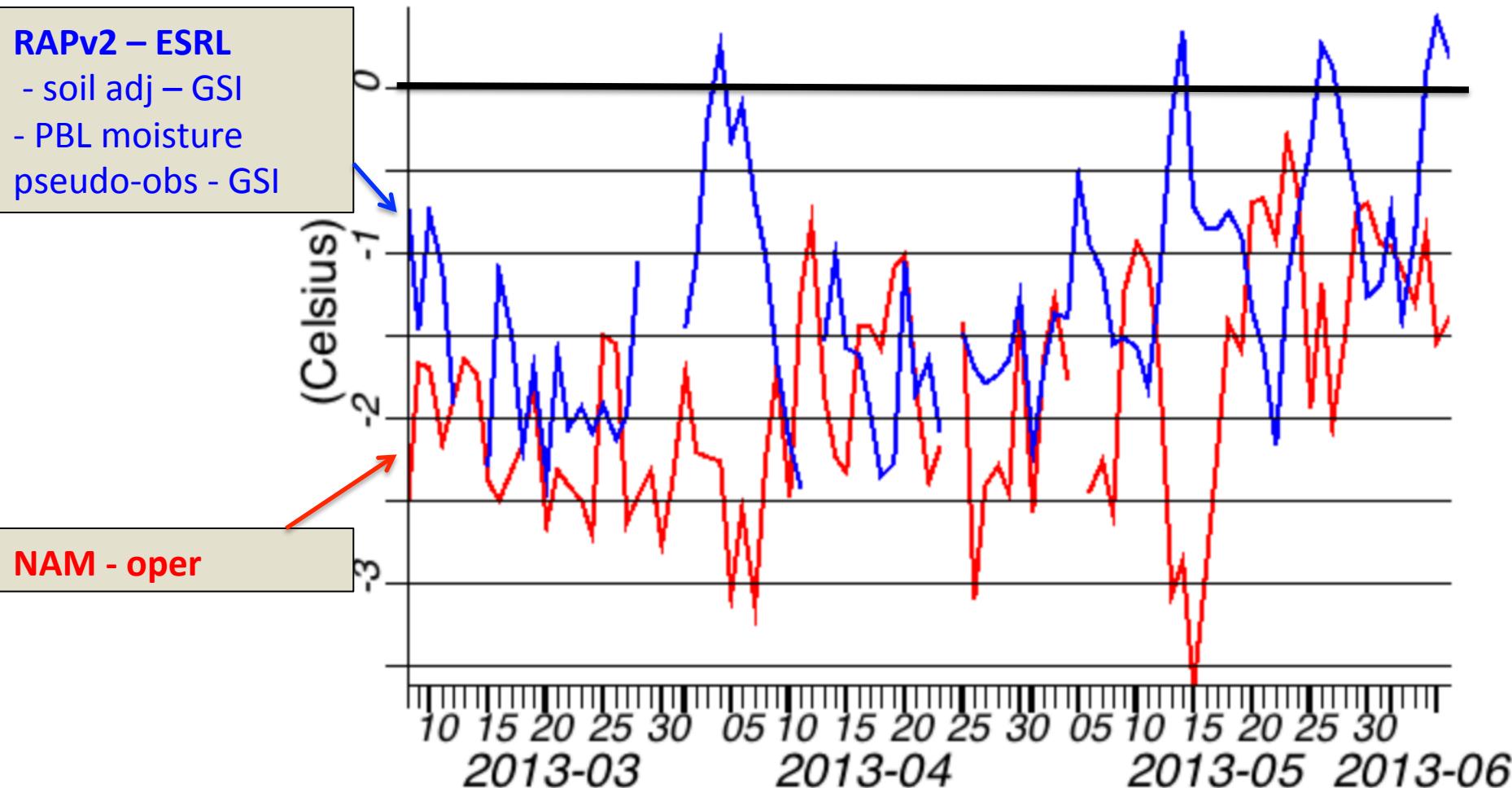
BIAS (Observed – Forecast) 01 Feb – 11 Feb 2013



Improved near-surface environment

12h forecast – 2m dewpoint bias (O-F) – valid 00z

— Bias for RR1h, E_HRRR rgn, 12h fcst of dewpoint, valid 0 UTC
— Bias for NAM, E_HRRR rgn, 12h fcst of dewpoint, valid 0 UTC





HRRR 2013 Pre-Forecast Hour

Temperature Tendency (i.e. Latent Heating) = f(Observed Reflectivity)

LH specified from reflectivity observations applied in four 15-min periods

NO digital filtering at 3-km

Reflectivity observations used to specify latent heating in previous 15-min period as follows:

- Positive heating rate where obs reflectivity ≥ 35 dBZ over depth ≥ 200 mb (avoids bright banding)**
- Zero heating rate where obs reflectivity ≤ 0 dBZ**
- Model microphysics heating rate preserved elsewhere**

$$LH(i, j, k) = \left(\frac{1000}{p} \right)^{R_d/c_p} \frac{(L_v + L_f)(f[Z_e])}{t * c_p}$$

LH = Latent Heating Rate (K/s)

p = Pressure

L_v = Latent heat of vaporization

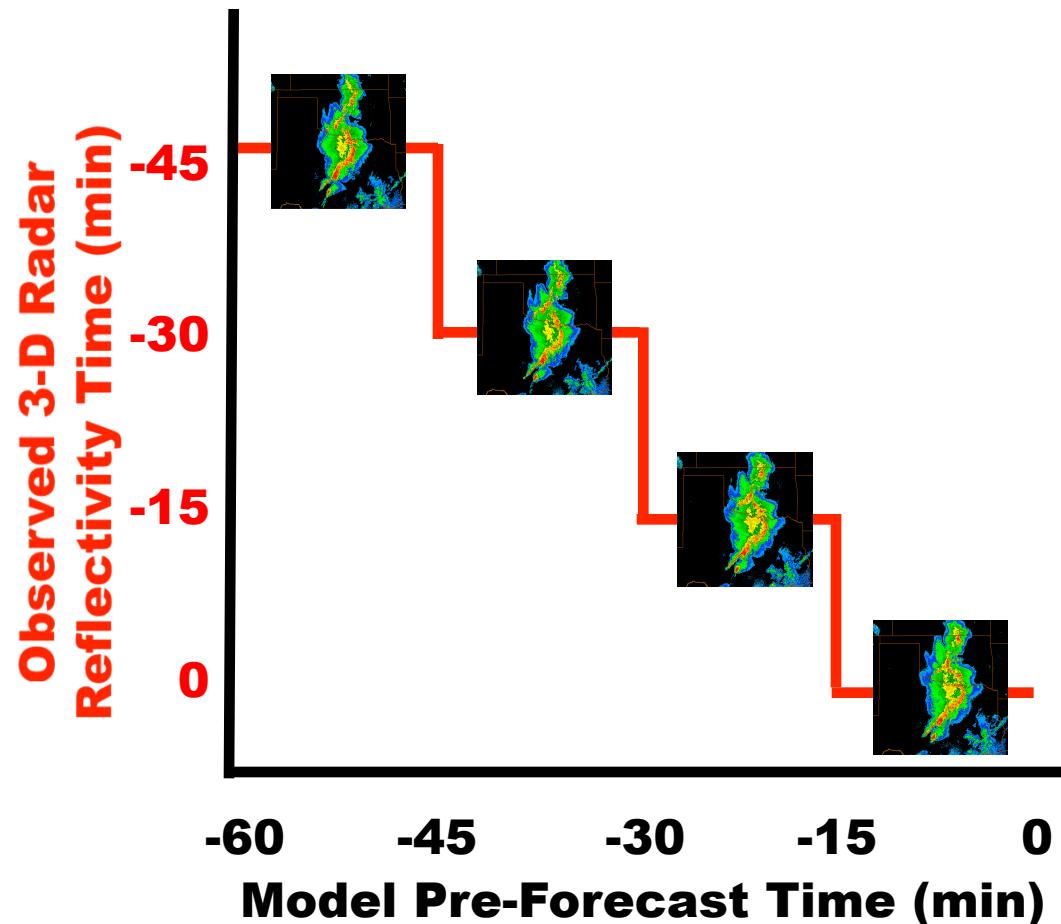
L_f = Latent heat of fusion

R_d = Dry gas constant

c_p = Specific heat of dry air at constant p

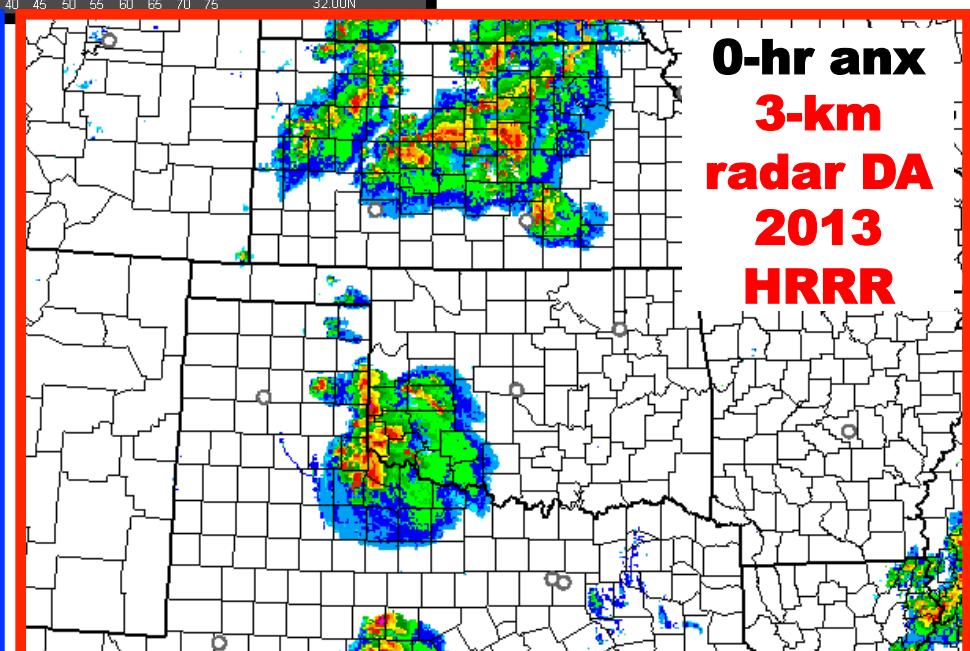
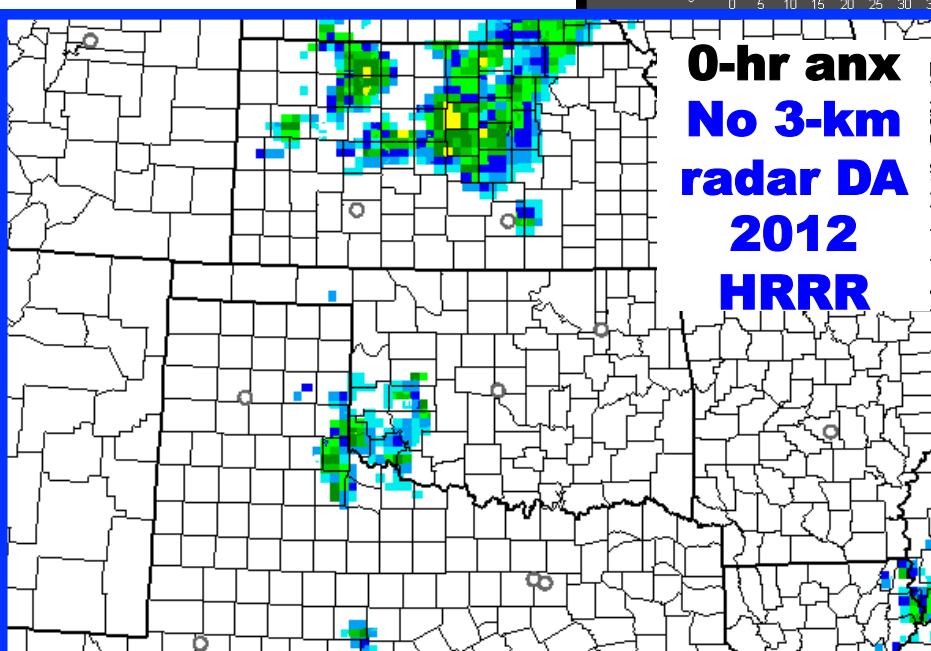
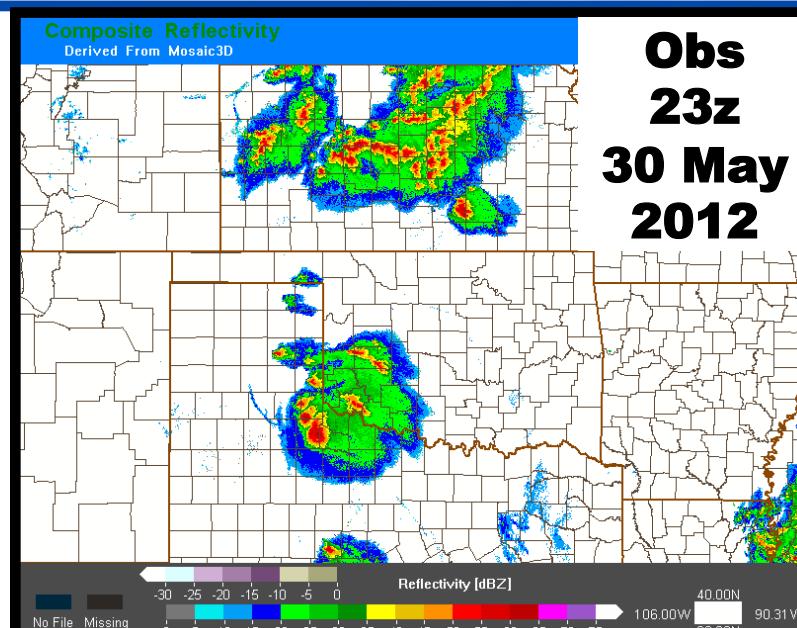
$f[Z_e]$ = Reflectivity factor converted to
rain/snow condensate

t = Time period of condensate formation
(300s i.e. 5 min)



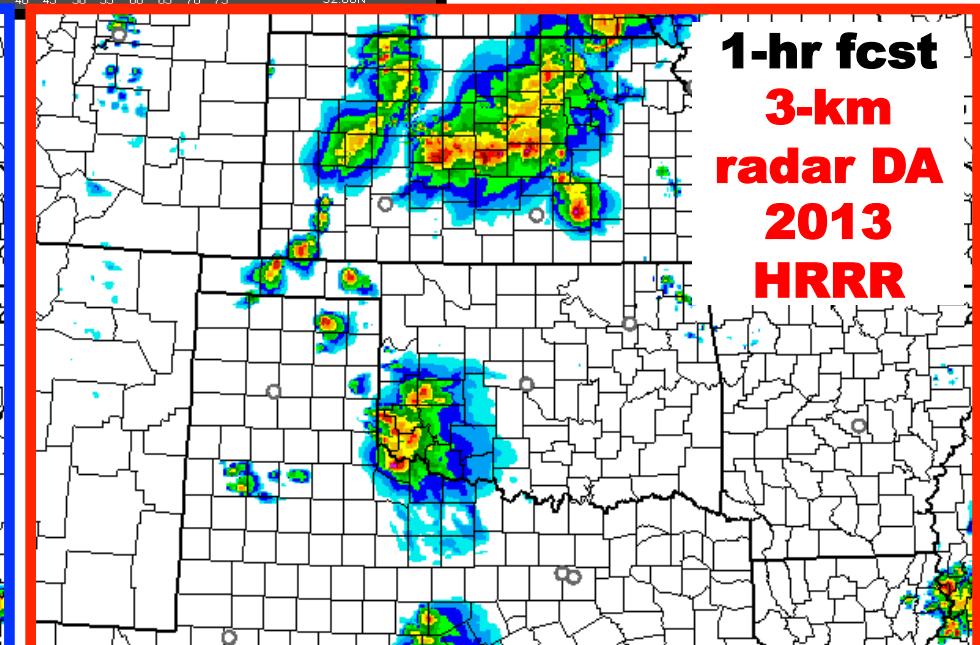
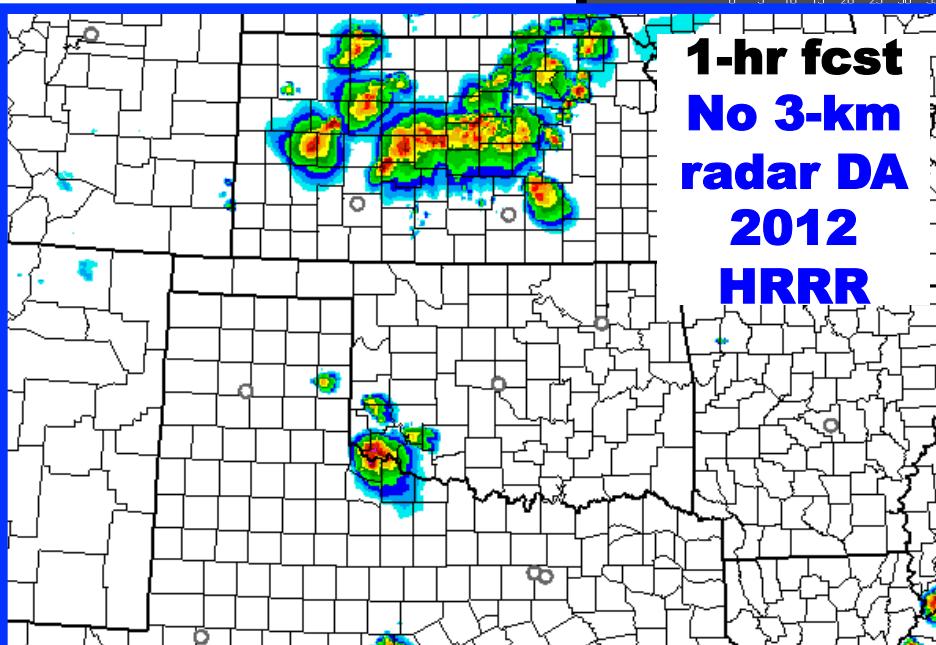
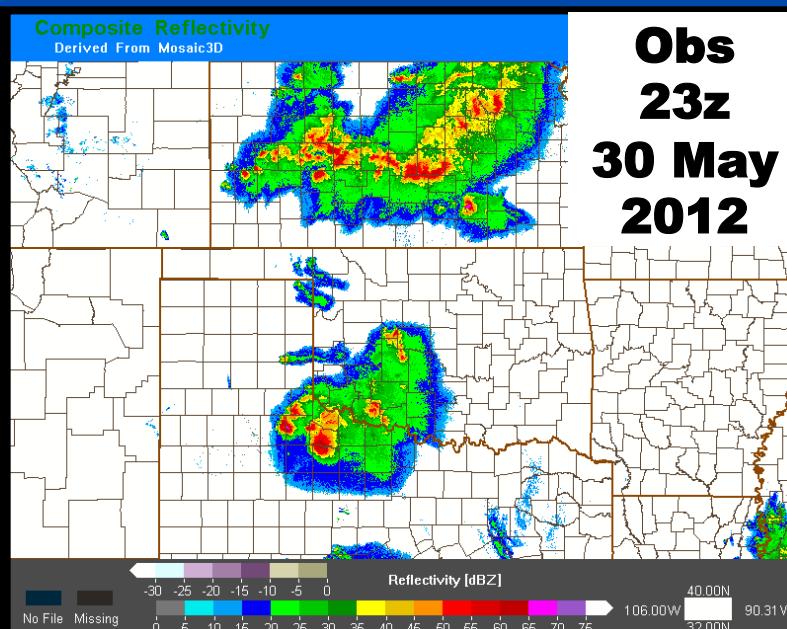


HRRR 2013 3-km GSI HM Analysis





HRRR 2013 3-km GSI HM Analysis





HRRR Reflectivity Verification

7-day retrospective period **May-June 2012**

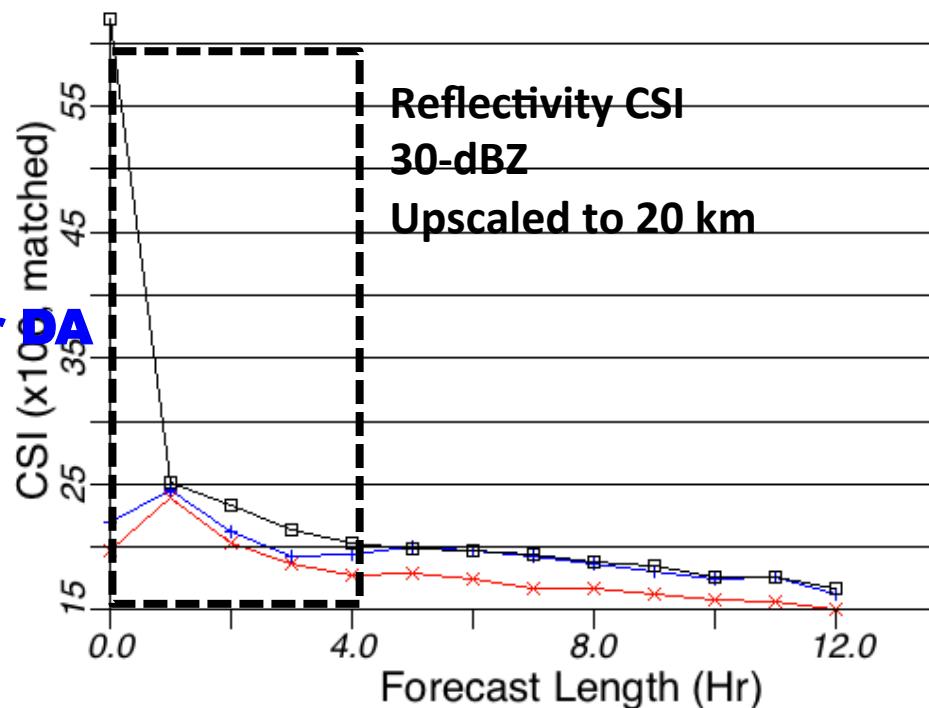
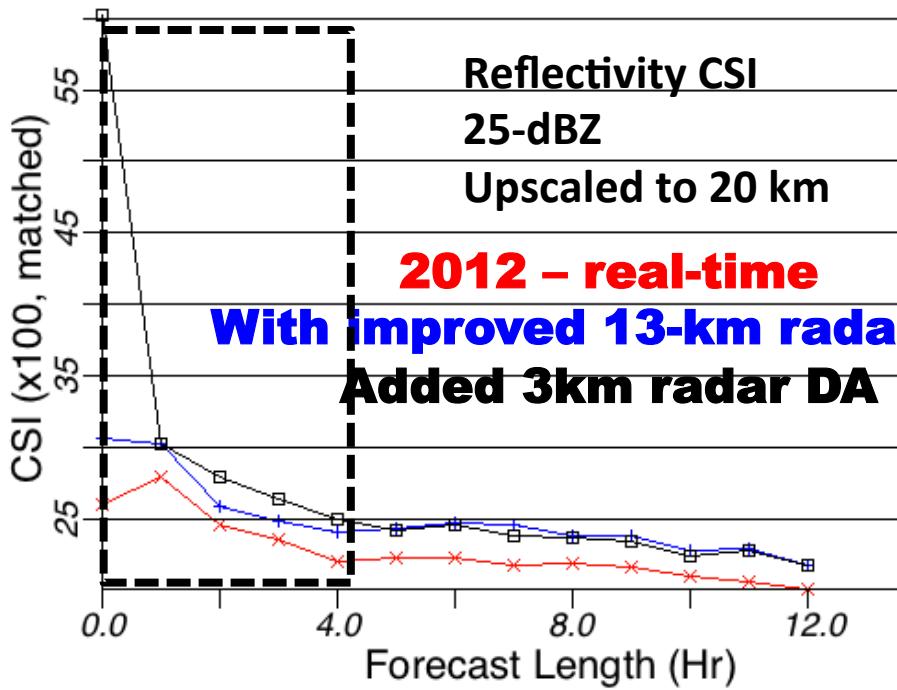
Forecasts every 2 hours

> 25/30 dBZ Composite Reflectivity

Eastern half of US

- CSI for HRRR_June_2012_v7_20km, EUS rgn, 25dBZ, All runs
- CSI for HRRR_June_2012_v6_20km, EUS rgn, 25dBZ, All runs
- CSI for HRRR_20km, EUS rgn, 25dBZ, All runs 2012-05-29

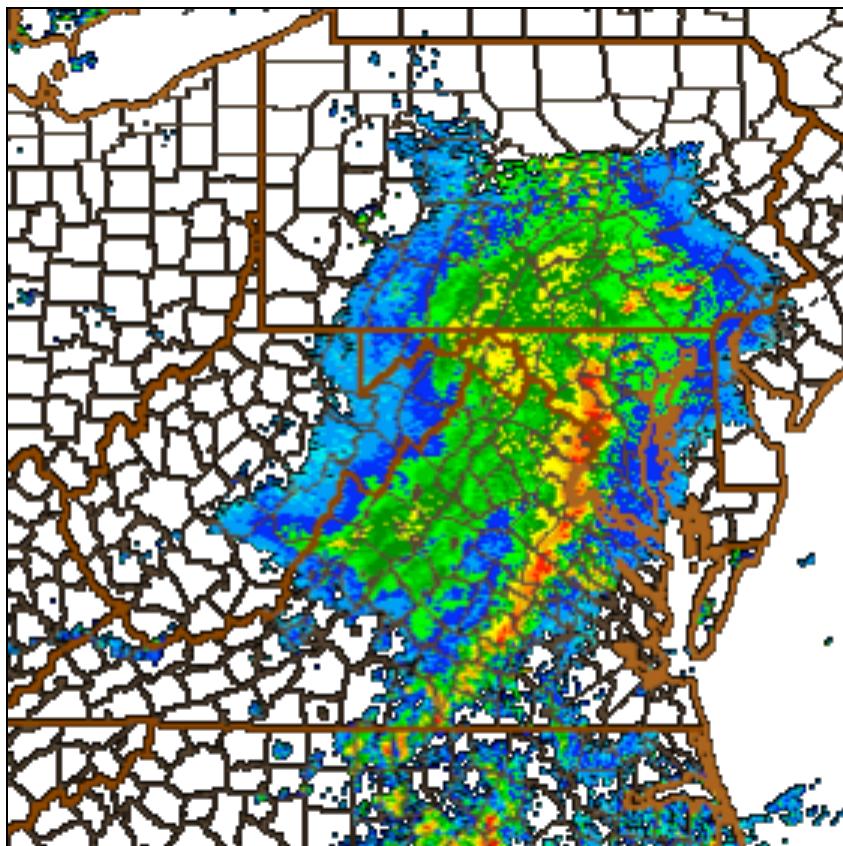
- CSI for HRRR_June_2012_v7_20km, EUS rgn, 30dBZ, All runs
- CSI for HRRR_June_2012_v6_20km, EUS rgn, 30dBZ, All runs
- CSI for HRRR_20km, EUS rgn, 30dBZ, All runs 2012-05-29



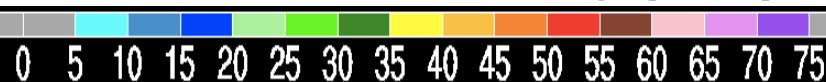
NOAA Next-Generation RAP / HRRR System

Forecast of Mid-Atlantic Derecho – 29 June 2012

Radar observed
Valid 11PM EDT

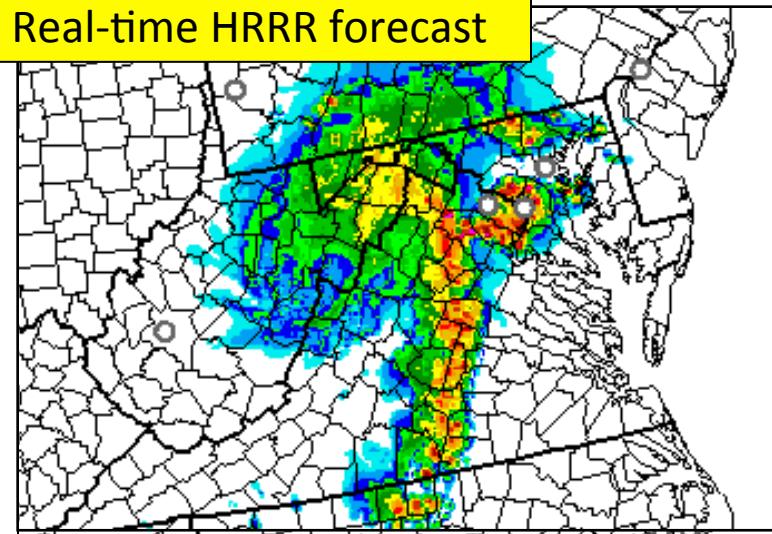


Composite Reflectivity (dBZ)

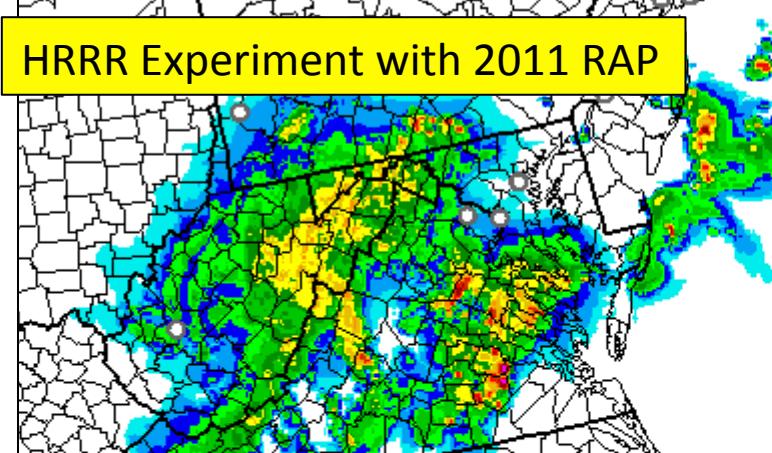


HRRR 12-h forecast

Real-time HRRR forecast



HRRR Experiment with 2011 RAP



*Conclusion – improved RAP DA in 2012 critical
for very good 29 June derecho forecast*



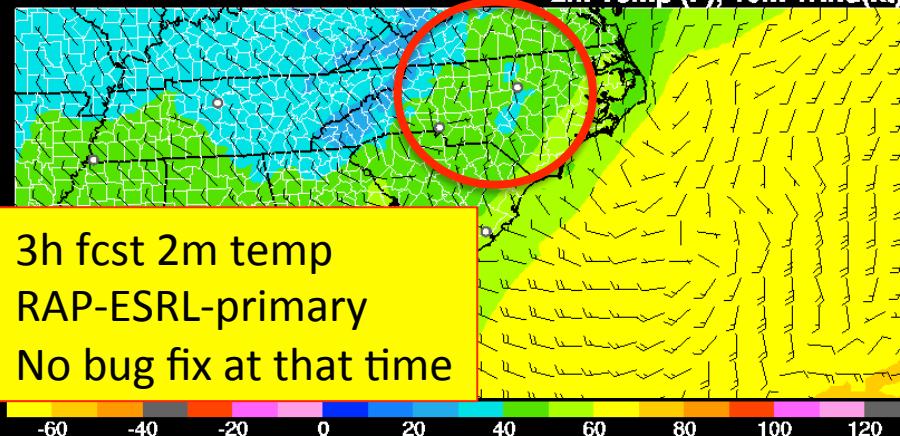
HRRR/RAPv2 changes for spring 2013

	Model	Data Assimilation
RAP-ESRL (13 km)	<p>WRFv3.4.1+ incl. physics changes (incl. snow-radiation fix)</p> <p><u>Physics changes:</u></p> <p>MYNN PBL scheme –Olson version 9-layer RUC LSM (from 6-layer) Modified roughness length Thompson microphysics update</p>	<p>Merge with GFS trunk GFS ensemble background error cov Stronger/symmetric soil adjustment, adapted for 9-layer LSM Radar hydrometeor building/clearing Snow cover building (added) /modified trimming (no low-level temp limit) Fractional cloud assimilation</p>
HR^RR (3 km)	<p>WRFv3.4.1+ incl. physics changes (incl. snow-radiation fix)</p> <p><u>Physics changes:</u></p> <p>MYNN PBL scheme -Olson version 9-layer RUC LSM (from 6-layer) Modified roughness length Thompson microphysics update</p>	<p>3 km/15 min radar reflectivity assimilation 3km GSI full-data assimilation for last pass, including 3km cloud/ hydrometeor assimilation</p> <p>Changes with high/medium importance for <i>overall</i> forecast skill</p>

RAP-primary-ESRL 02/16/2013 (15:00) 3 hr fcst

Valid 02/16/2013 18:00 UTC

2m Temp (F), 10m Wind(kt)



RAP-dev1 02/16/2013 (15:00) 3 hr fcst

Valid 02/16/2013 18:00 UTC

2m Temp (F), 10m Wind(kt)



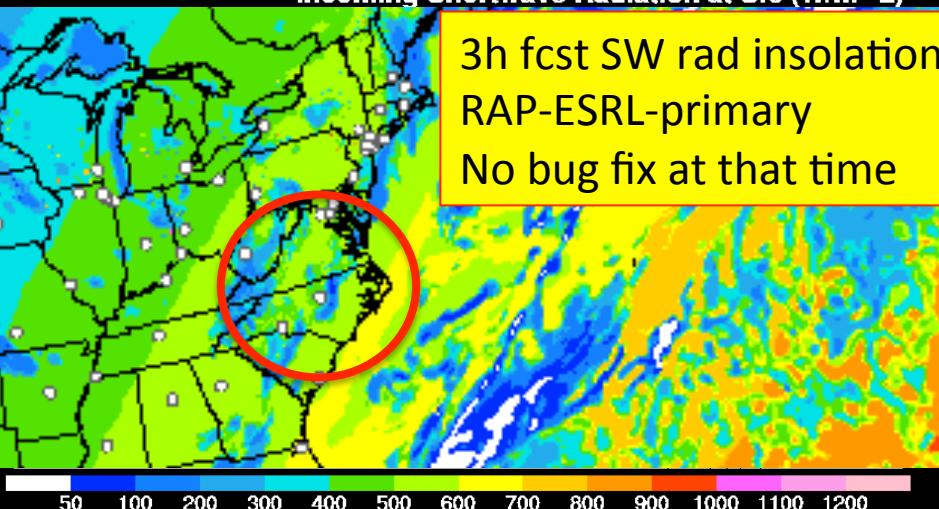
RAP-NCEP 2m temp/ptype bust Sat 16 February 2013

Courtesy - Jonathan Blaes – NWS Raleigh

Traced to WRF radiation bug – no attenuation for snow mixing ratio

RAP-primary-ESRL 02/16/2013 (12:00) 3h fcst - Experimental Valid 02/16/2013 15:00 UTC

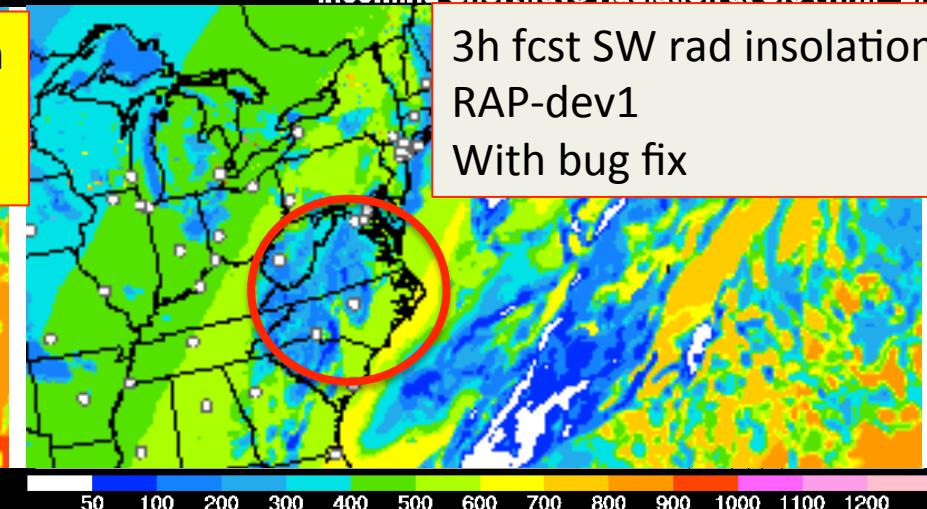
Incoming Shortwave Radiation at Sfc (W/m**2)

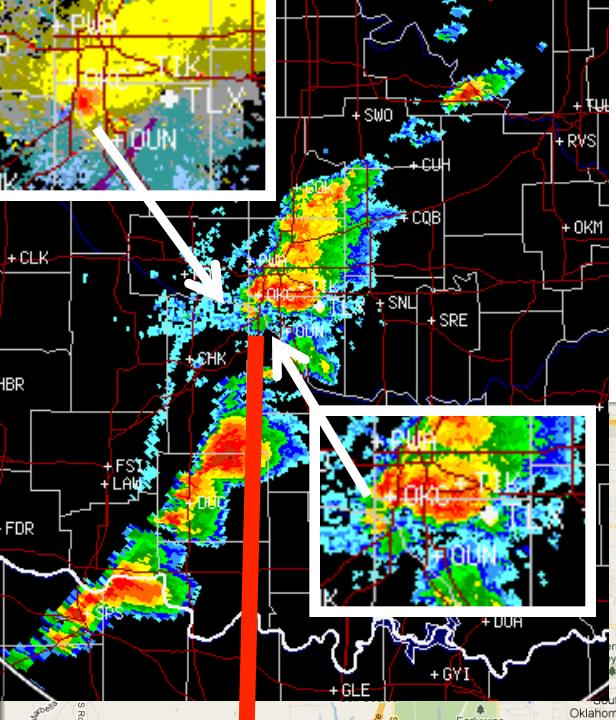


RAP-dev1 02/16/2013 (12:00) 3h fcst - Experimental

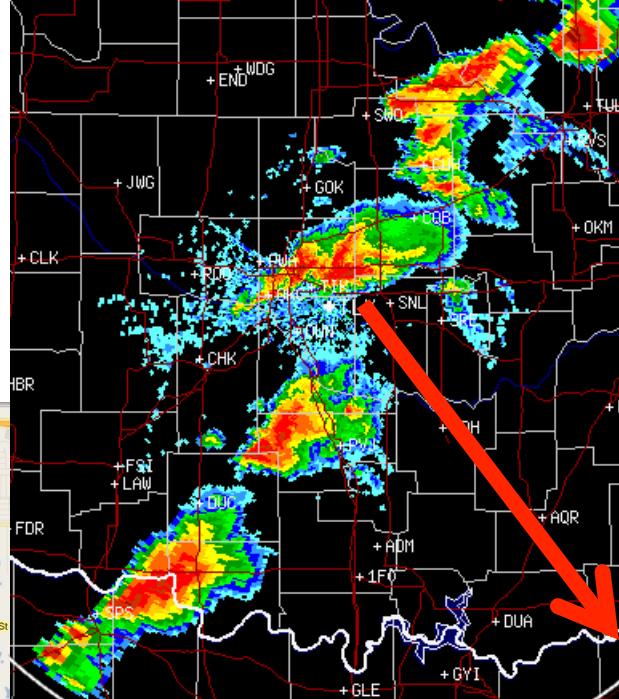
Valid 02/16/2013 15:00 UTC

Incoming Shortwave Radiation at Sfc (W/m**2)





**20 UTC
3 PM**



**21 UTC
4 PM**



20 MAY 2013 MOORE OK TORNADO

©2013 Weather Graphics

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x VELOCITY DIPOLE INDICATING TORNADO LOCATION

o SPECTRUM WIDTH DEBRIS SIGNATURE

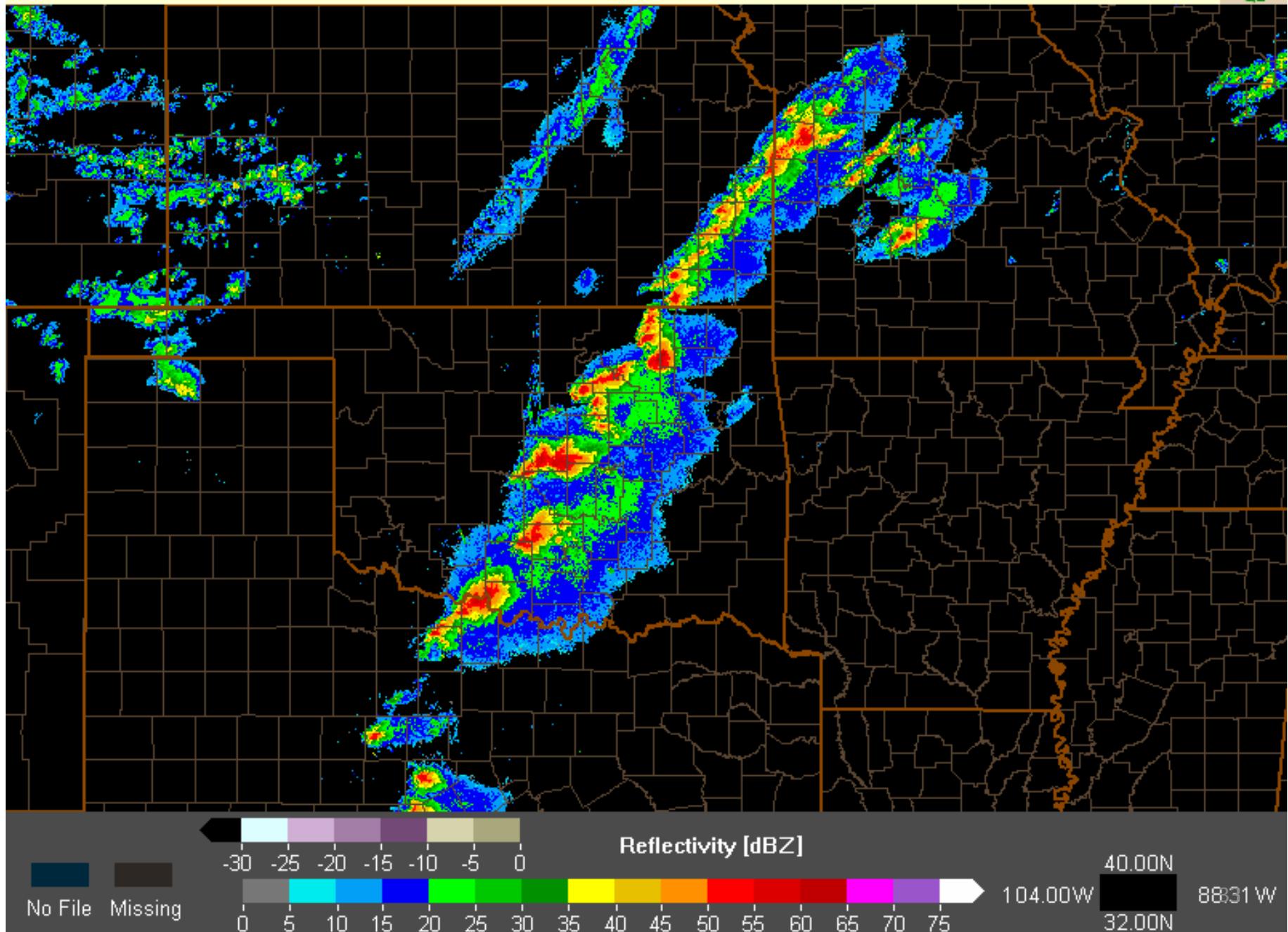
TRACK IS NOT PRECISE -- THIS IS AN ESTIMATE ONLY.

Composite Reflectivity

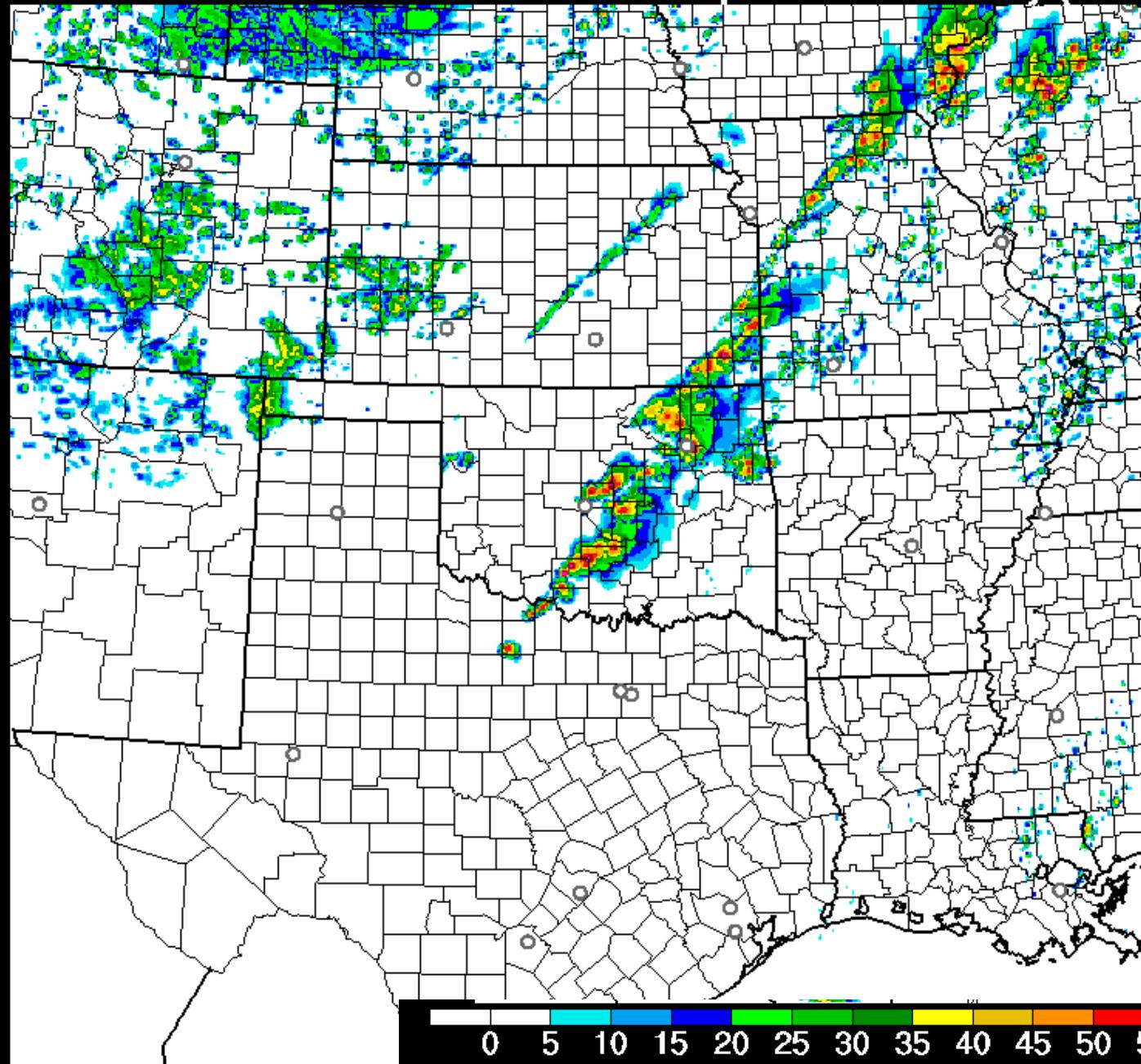
Derived From Mosaic3D

Valid At:

05/20/2013 21:00:00 UTC



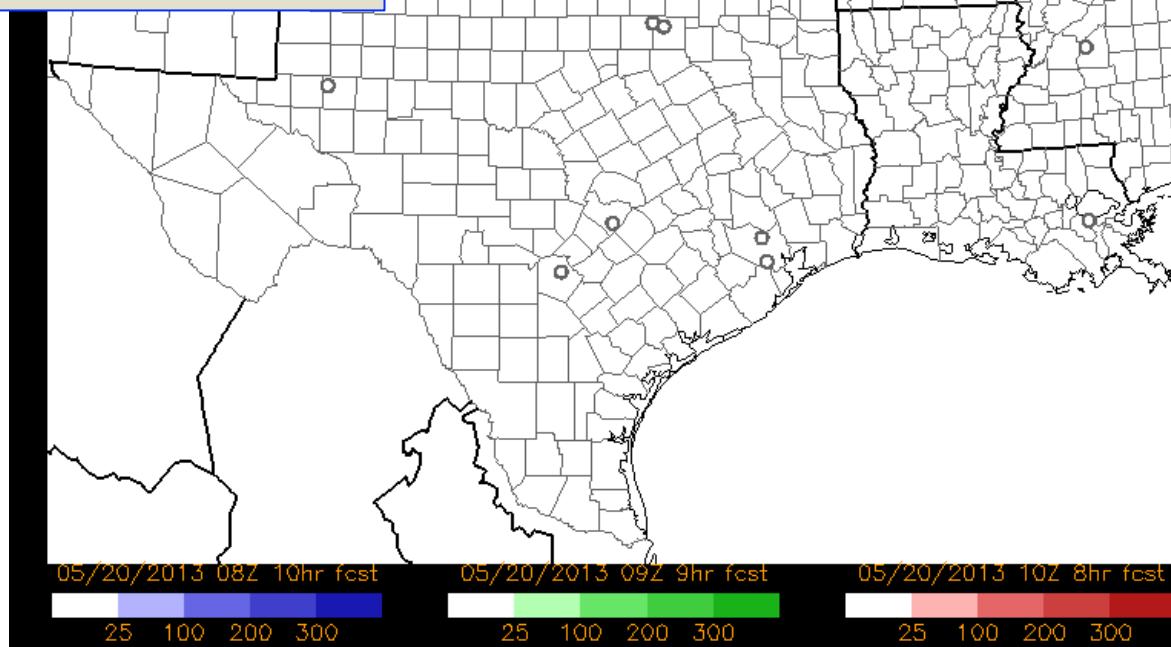
HRRR 05/20/2013 (13:00) 08:00 hr fcst - Experimental Valid 05/20/2013 21:00 UTC
Composite Reflectivity (dBz)



HRRR 05/20/2013 (10:00) 8h fcst - Experimental

Valid 05/20/2013 18:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

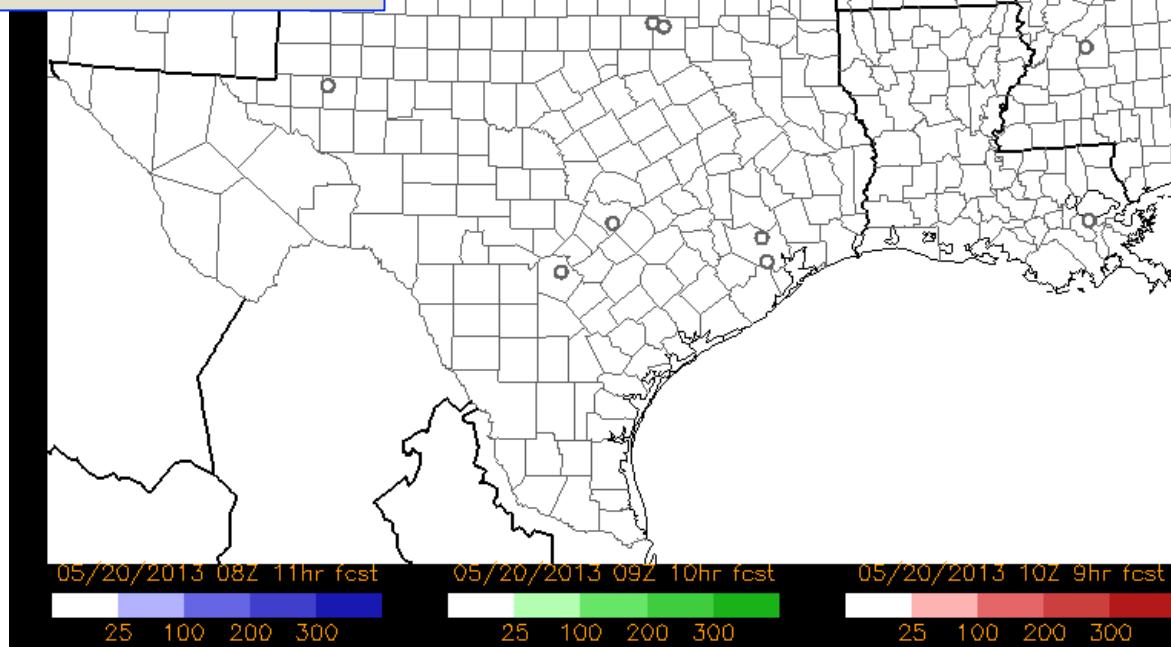
3-member HRRR
ensemble
Max 1h updraft
helicity



HRRR 05/20/2013 (10:00) 9h fcst - Experimental

Valid 05/20/2013 19:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

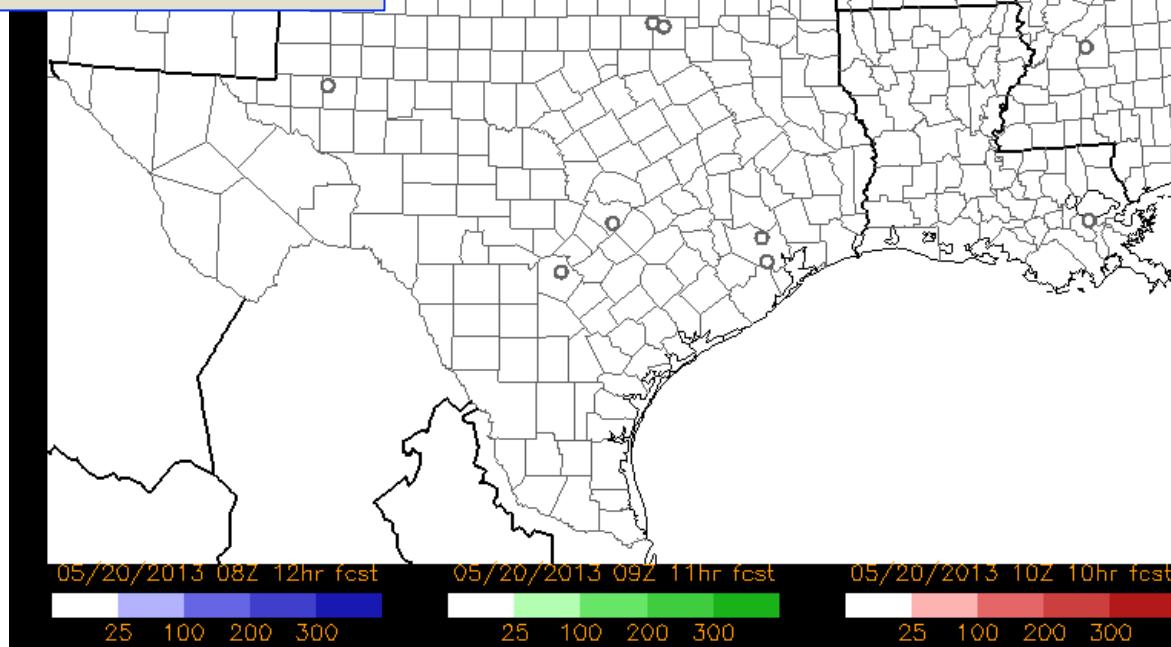
3-member HRRR
ensemble
Max 1h updraft
helicity



HRRR 05/20/2013 (10:00) 10h fcst - Experimental

Valid 05/20/2013 20:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

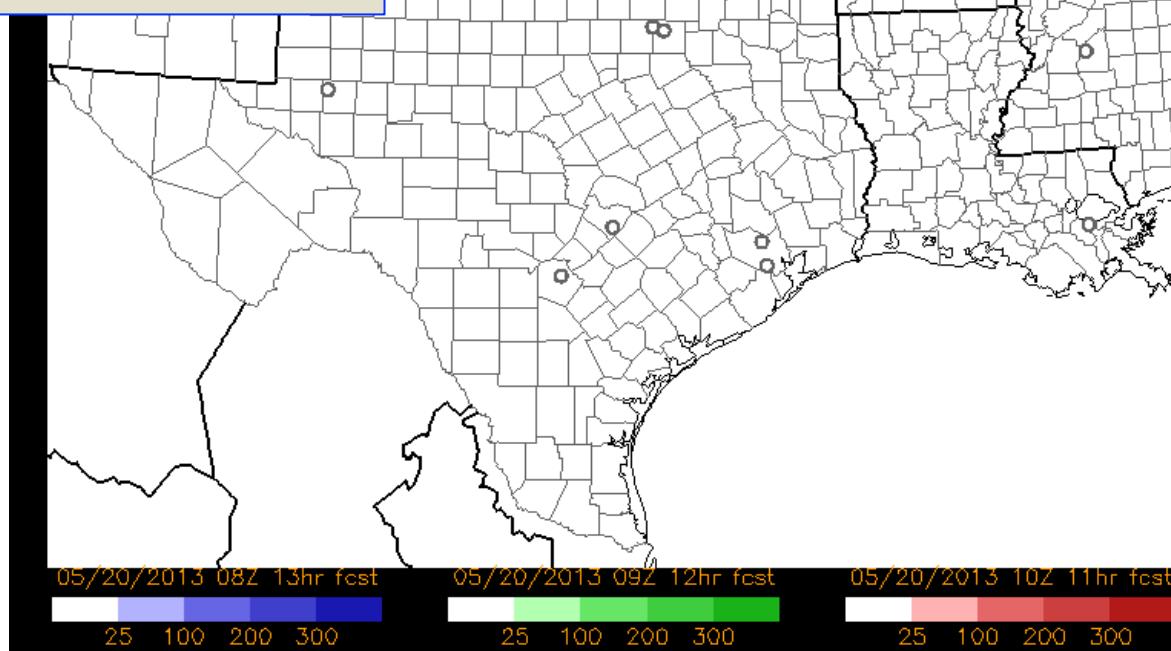
3-member HRRR ensemble
Max 1h updraft helicity



HRRR 05/20/2013 (10:00) 11h fcst - Experimental

Valid 05/20/2013 21:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

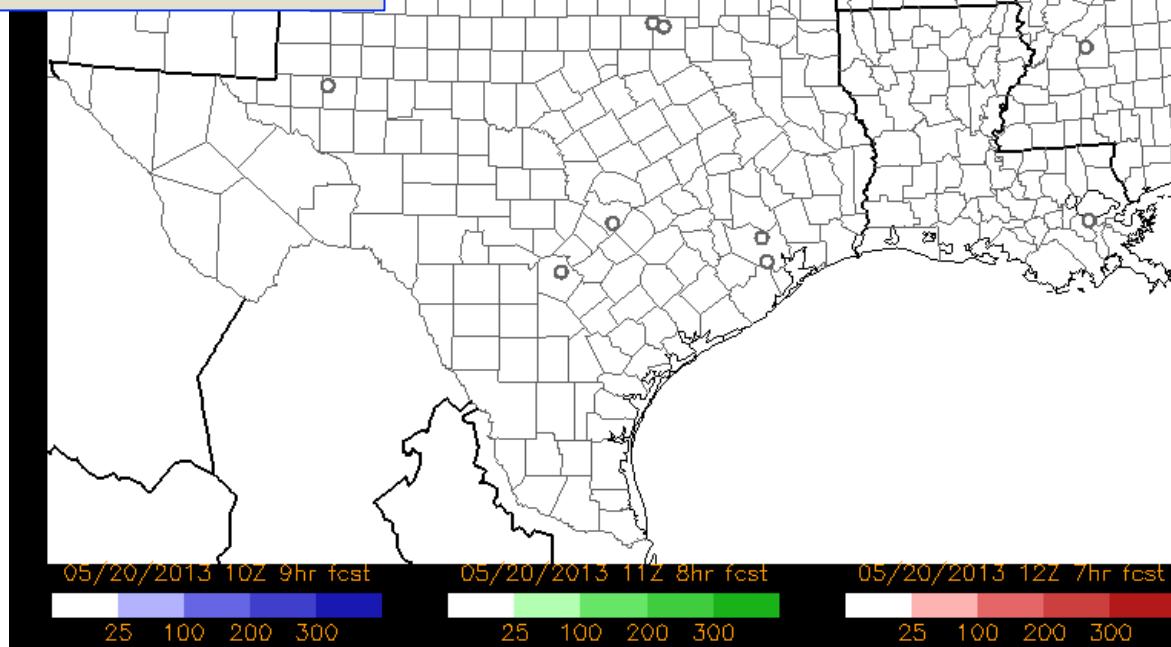
3-member HRRR ensemble
Max 1h updraft helicity



HRRR 05/20/2013 (12:00) 7h fcst - Experimental

Valid 05/20/2013 19:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

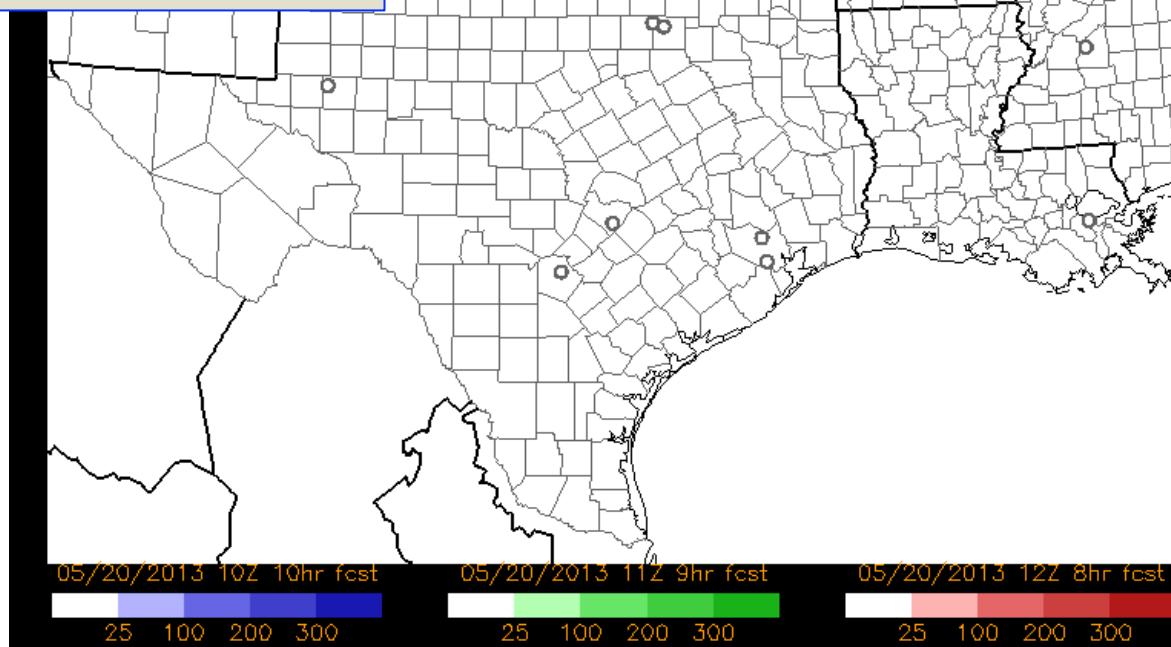
3-member HRRR
ensemble
Max 1h updraft
helicity



HRRR 05/20/2013 (12:00) 8h fcst - Experimental

Valid 05/20/2013 20:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

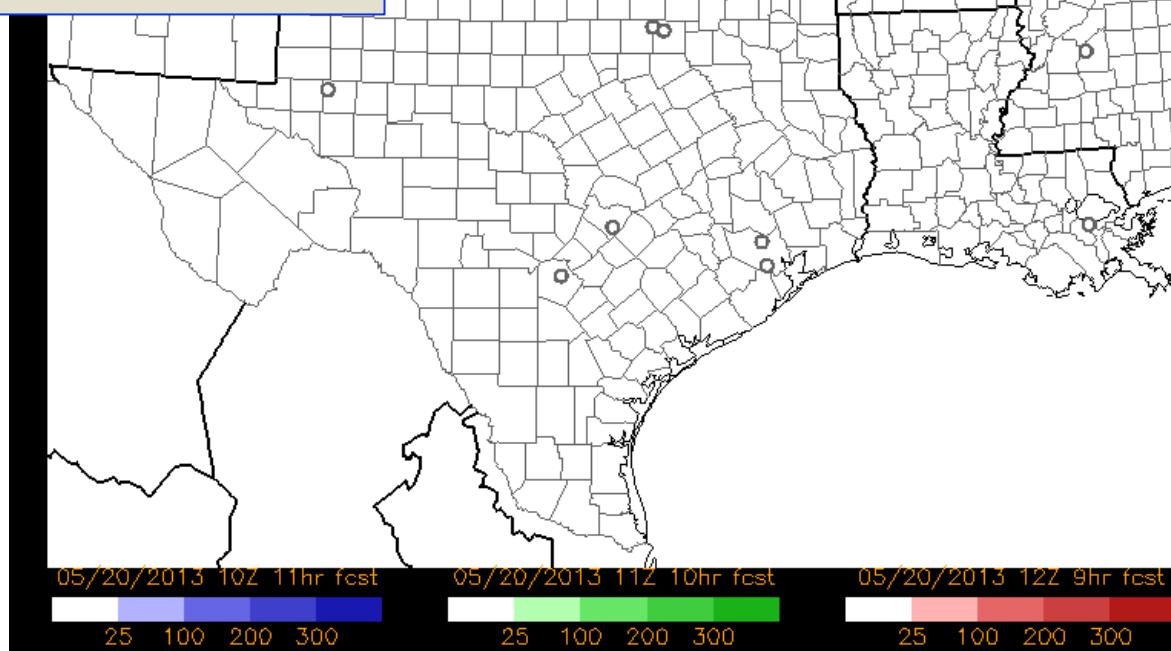
3-member HRRR
ensemble
Max 1h updraft
helicity



HRRR 05/20/2013 (12:00) 9h fcst - Experimental

Valid 05/20/2013 21:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

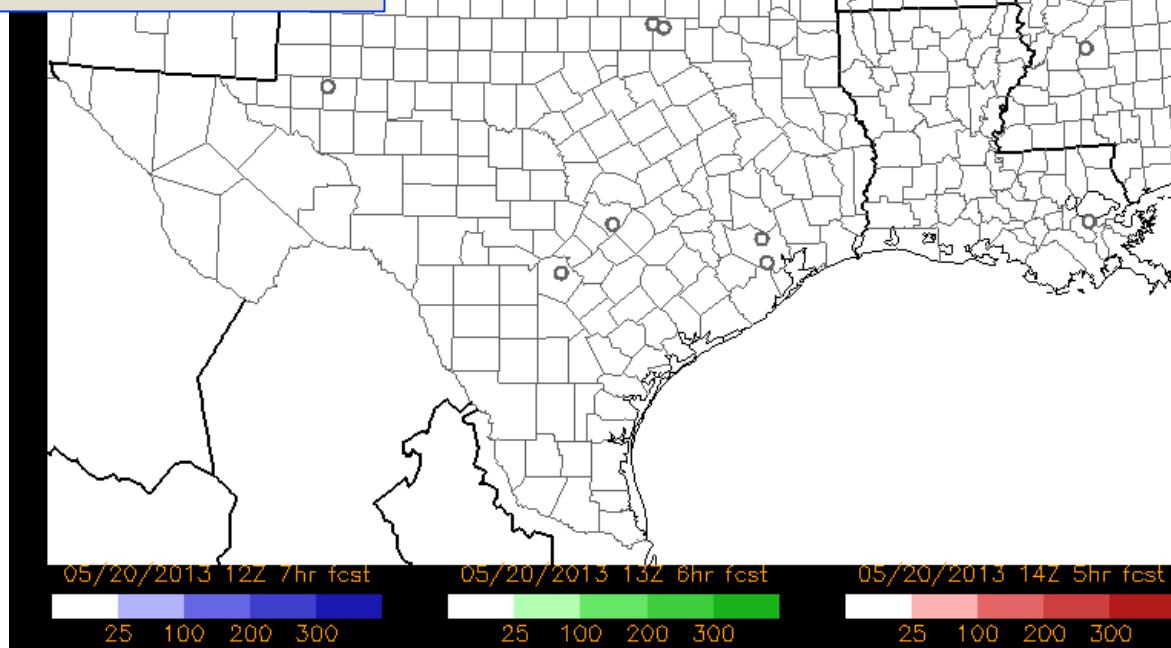
3-member HRRR
ensemble
Max 1h updraft
helicity



HRRR 05/20/2013 (14:00) 5h fcst - Experimental

Valid 05/20/2013 19:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

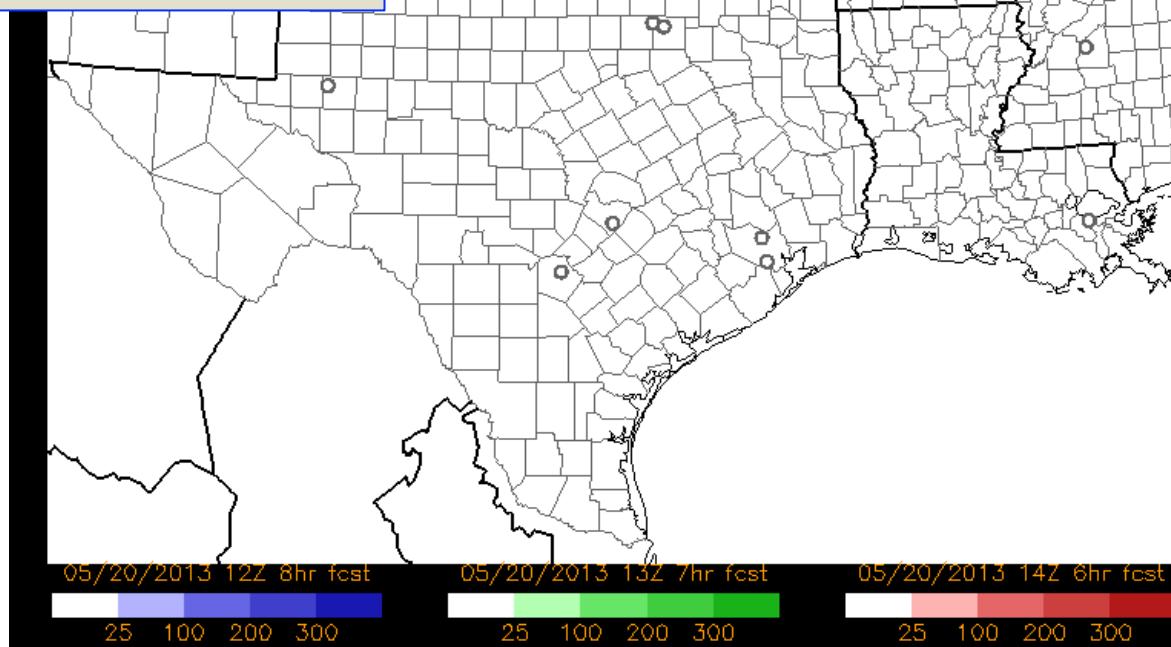
3-member HRRR
ensemble
Max 1h updraft
helicity



HRRR 05/20/2013 (14:00) 6h fcst - Experimental

Valid 05/20/2013 20:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

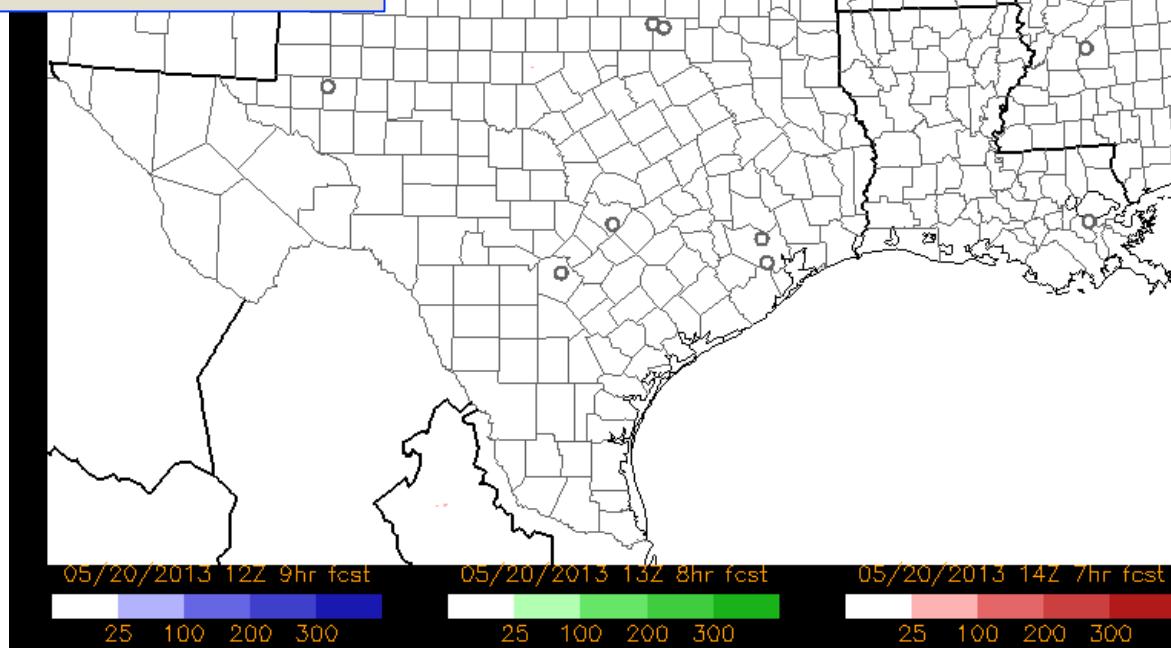
3-member HRRR
ensemble
Max 1h updraft
helicity



HRRR 05/20/2013 (14:00) 7h fcst - Experimental

Valid 05/20/2013 21:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

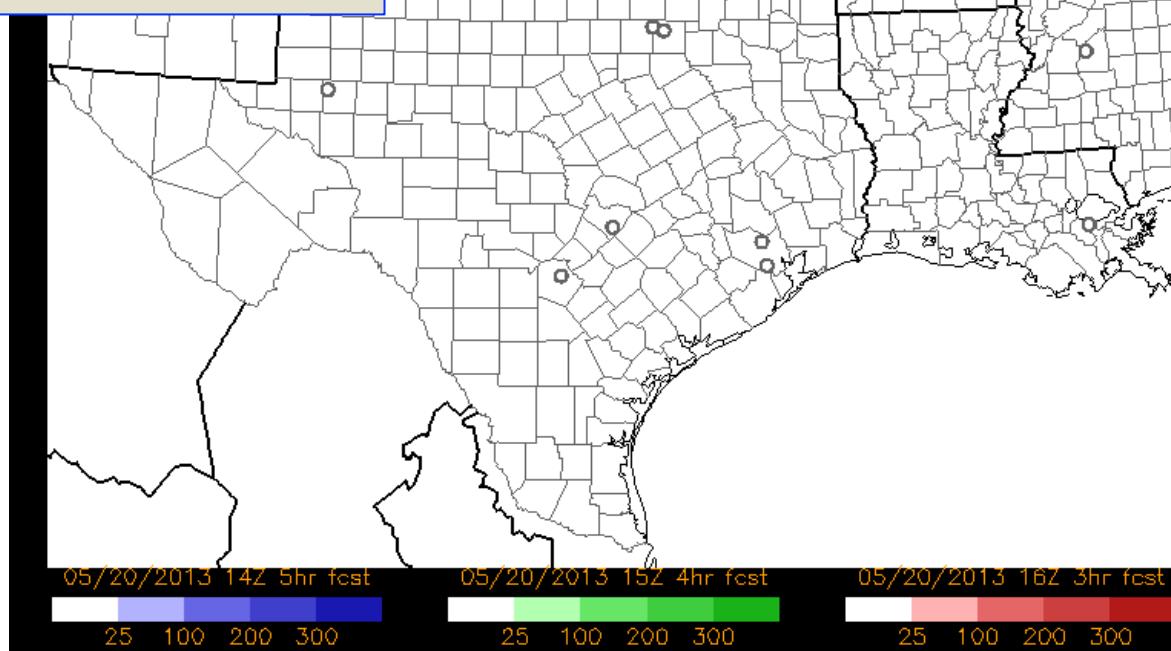
3-member HRRR
ensemble
Max 1h updraft
helicity



HRRR 05/20/2013 (16:00) 3h fcst - Experimental

Valid 05/20/2013 19:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

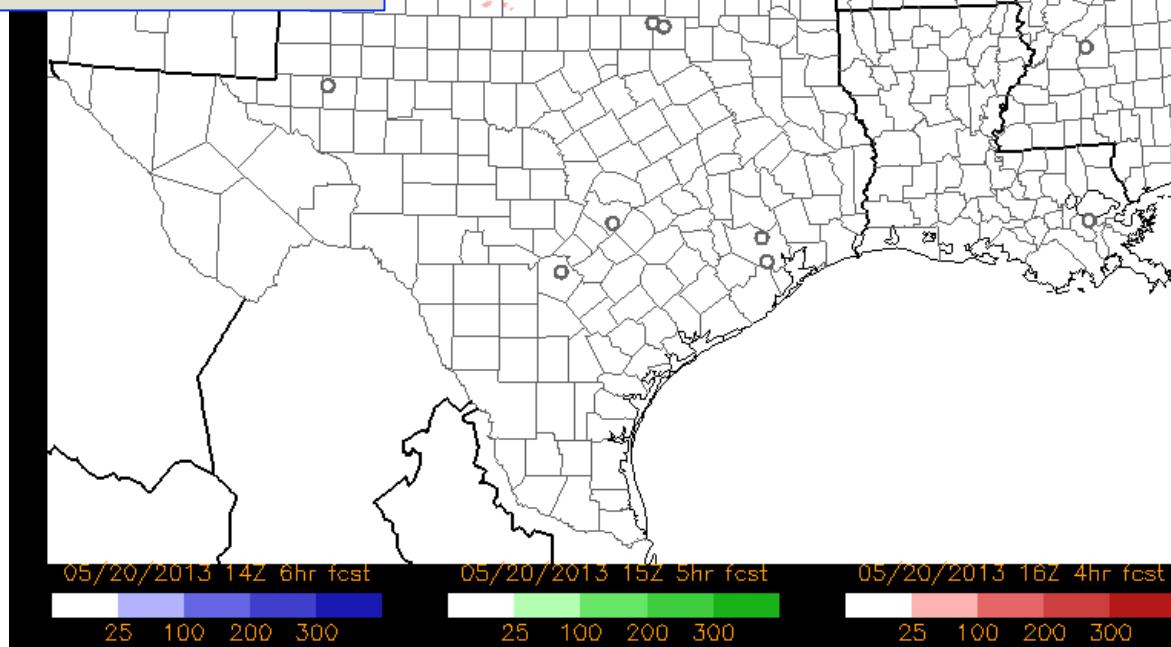
3-member HRRR
ensemble
Max 1h updraft
helicity



HRRR 05/20/2013 (16:00) 4h fcst - Experimental

Valid 05/20/2013 20:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

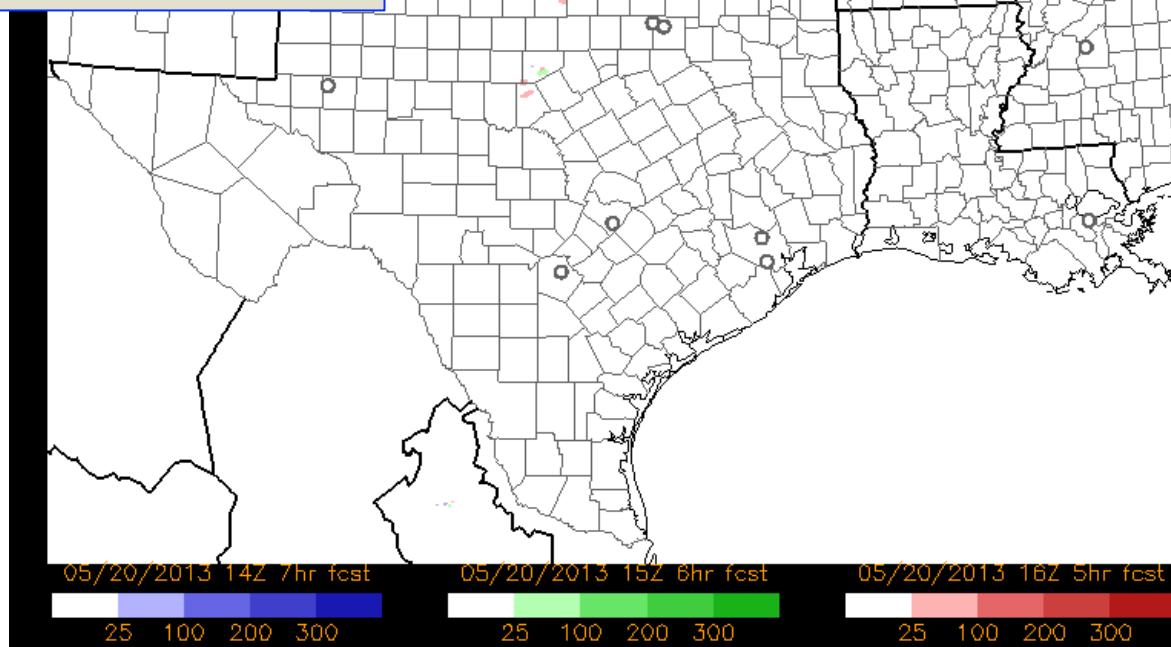
3-member HRRR
ensemble
Max 1h updraft
helicity



HRRR 05/20/2013 (16:00) 5h fcst - Experimental

Valid 05/20/2013 21:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

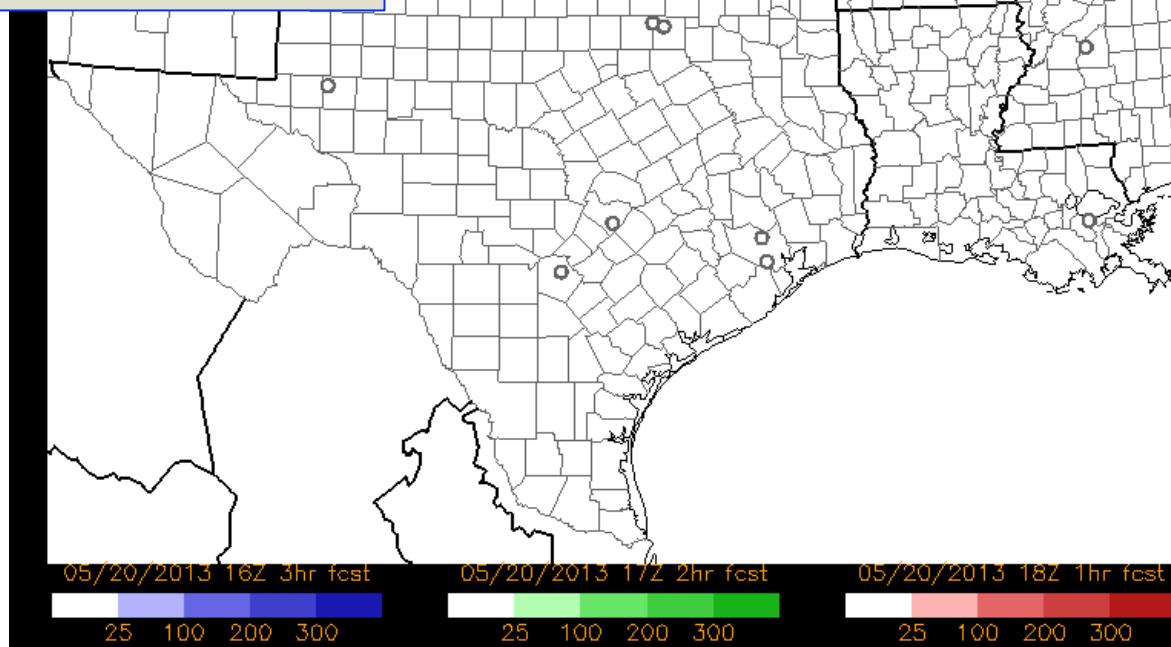
3-member HRRR
ensemble
Max 1h updraft
helicity



HRRR 05/20/2013 (18:00) 1h fcst - Experimental

Valid 05/20/2013 19:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

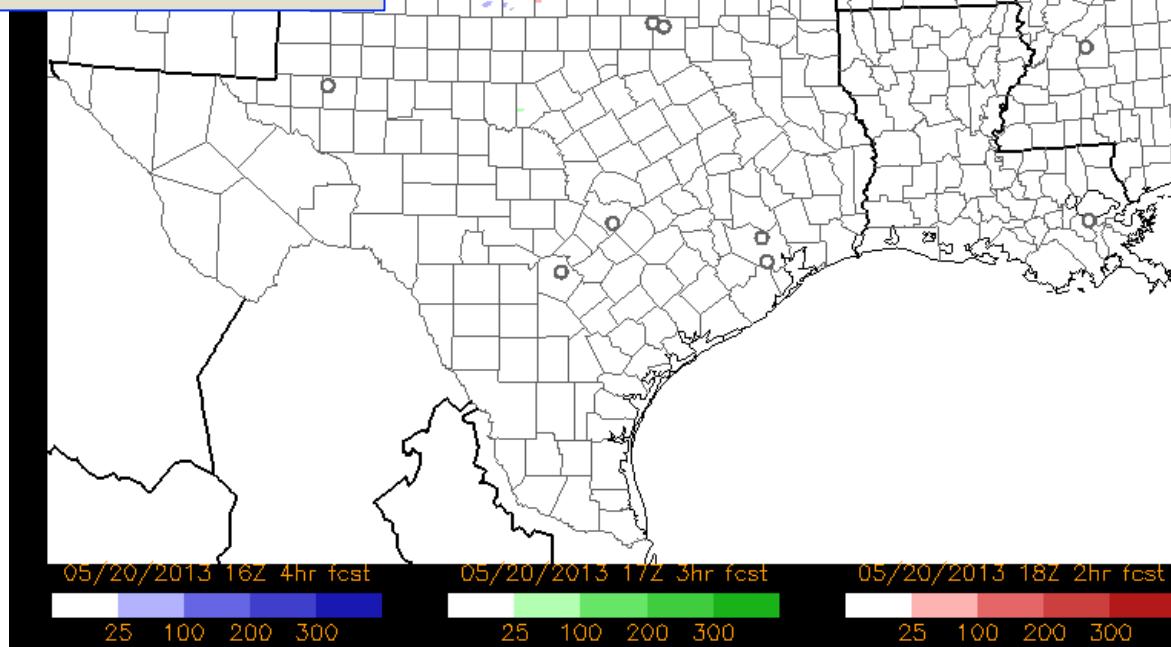
3-member HRRR
ensemble
Max 1h updraft
helicity



HRRR 05/20/2013 (18:00) 2h fcst - Experimental

Valid 05/20/2013 20:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

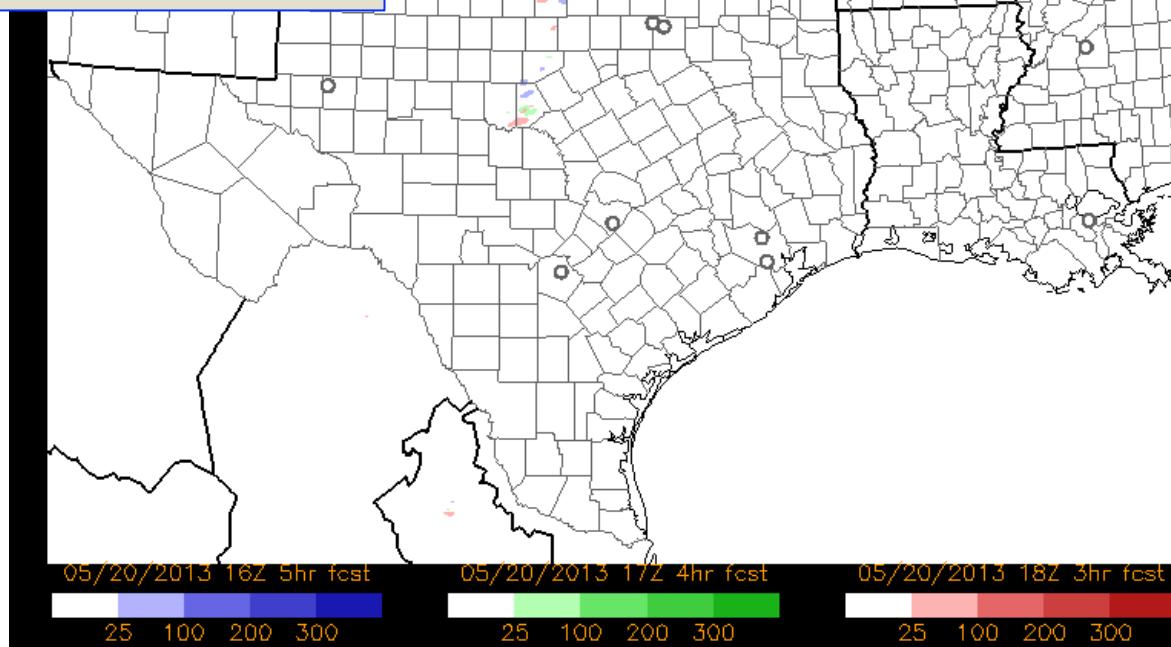
3-member HRRR
ensemble
Max 1h updraft
helicity



HRRR 05/20/2013 (18:00) 3h fcst - Experimental

Valid 05/20/2013 21:00 UTC
Ensemble Max Updraft Helicity (over prev hour) (m^2/s^2)

3-member HRRR
ensemble
Max 1h updraft
helicity

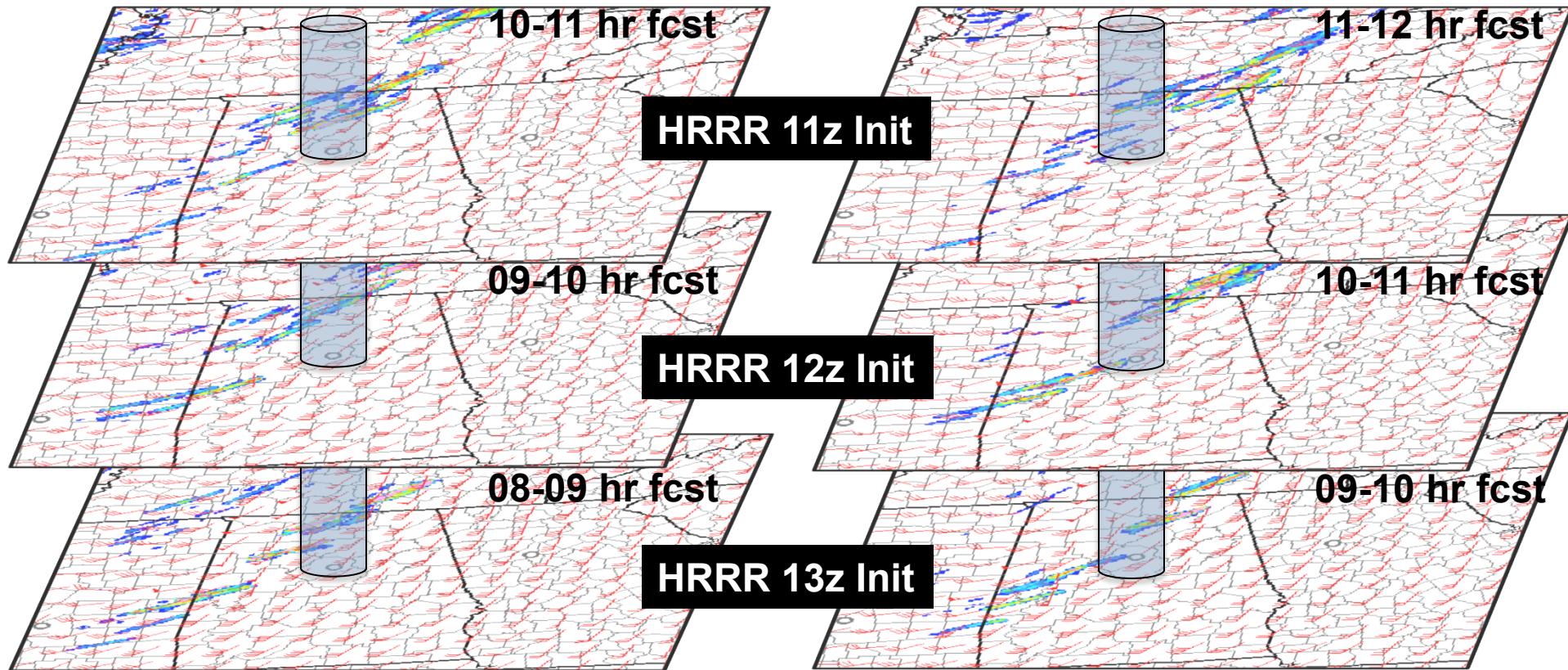




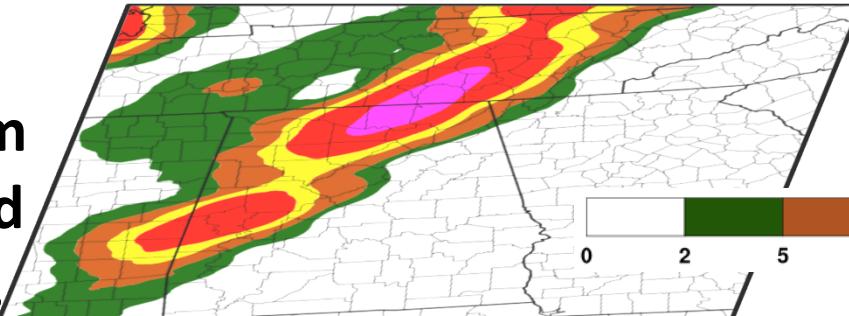
Time-lagged Ensemble

Forecasts valid 21-22z 27 April 2011

Forecasts valid 22-23z 27 April 2011



All six forecasts
combined to form
probabilities valid
22z 27 April 2011

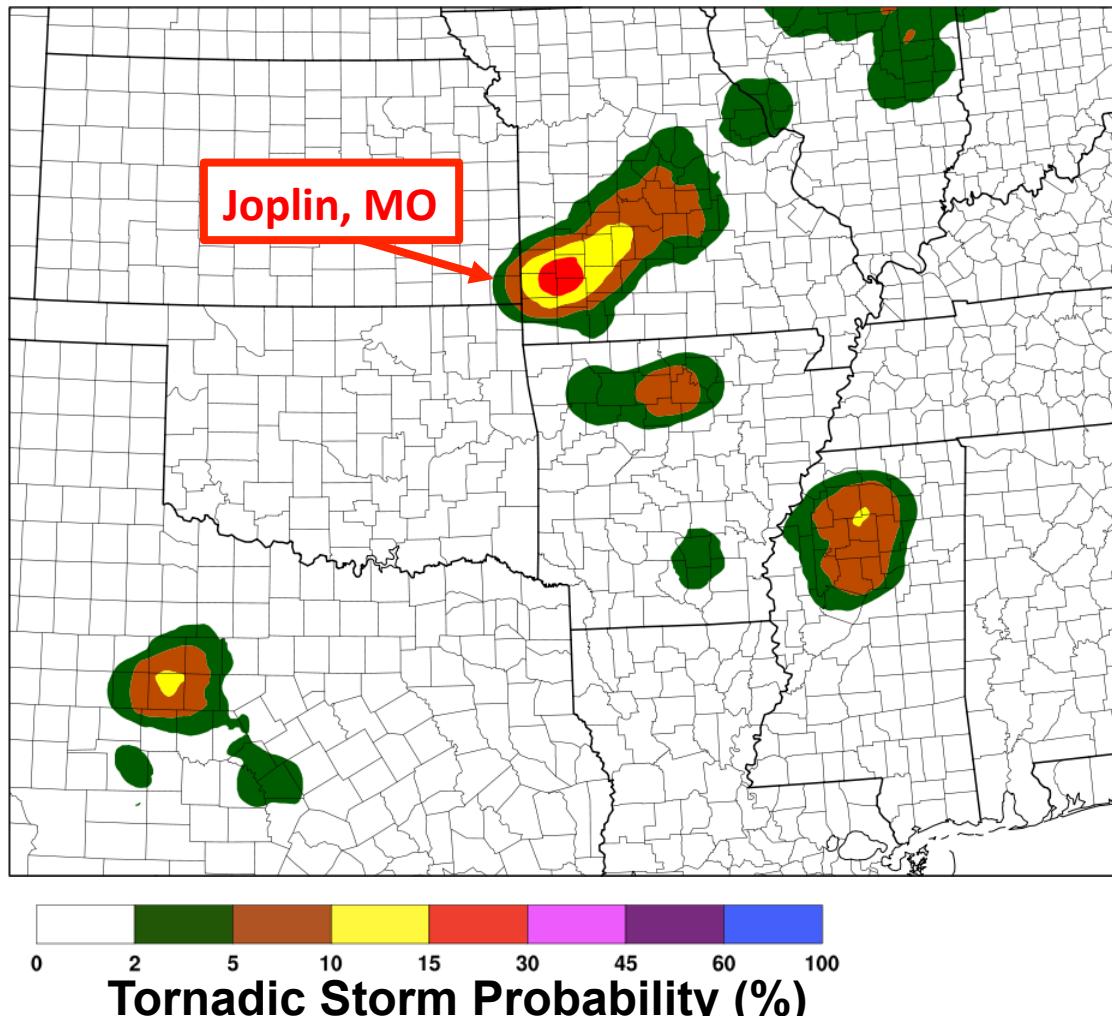


Spatial radius 45 km
Time radius 1 hr
UH threshold 25 m²/s²

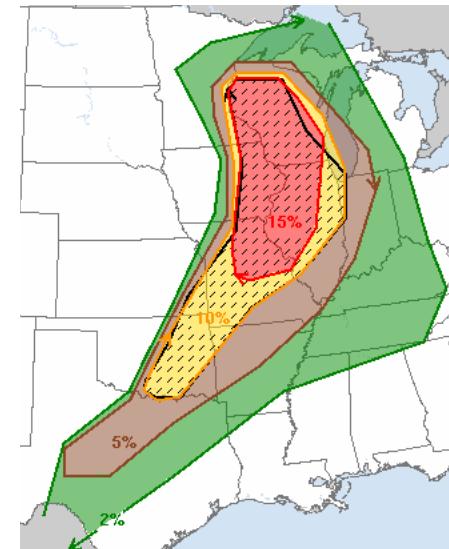


Example: 22 May 2011

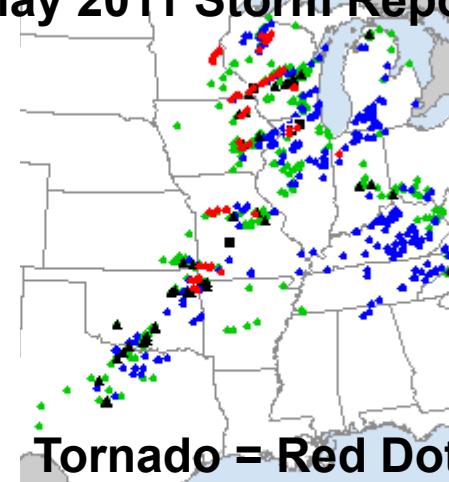
13z + 11hr fcst
Valid 00z 23 May 2011



1300z SPC Tornado Probability

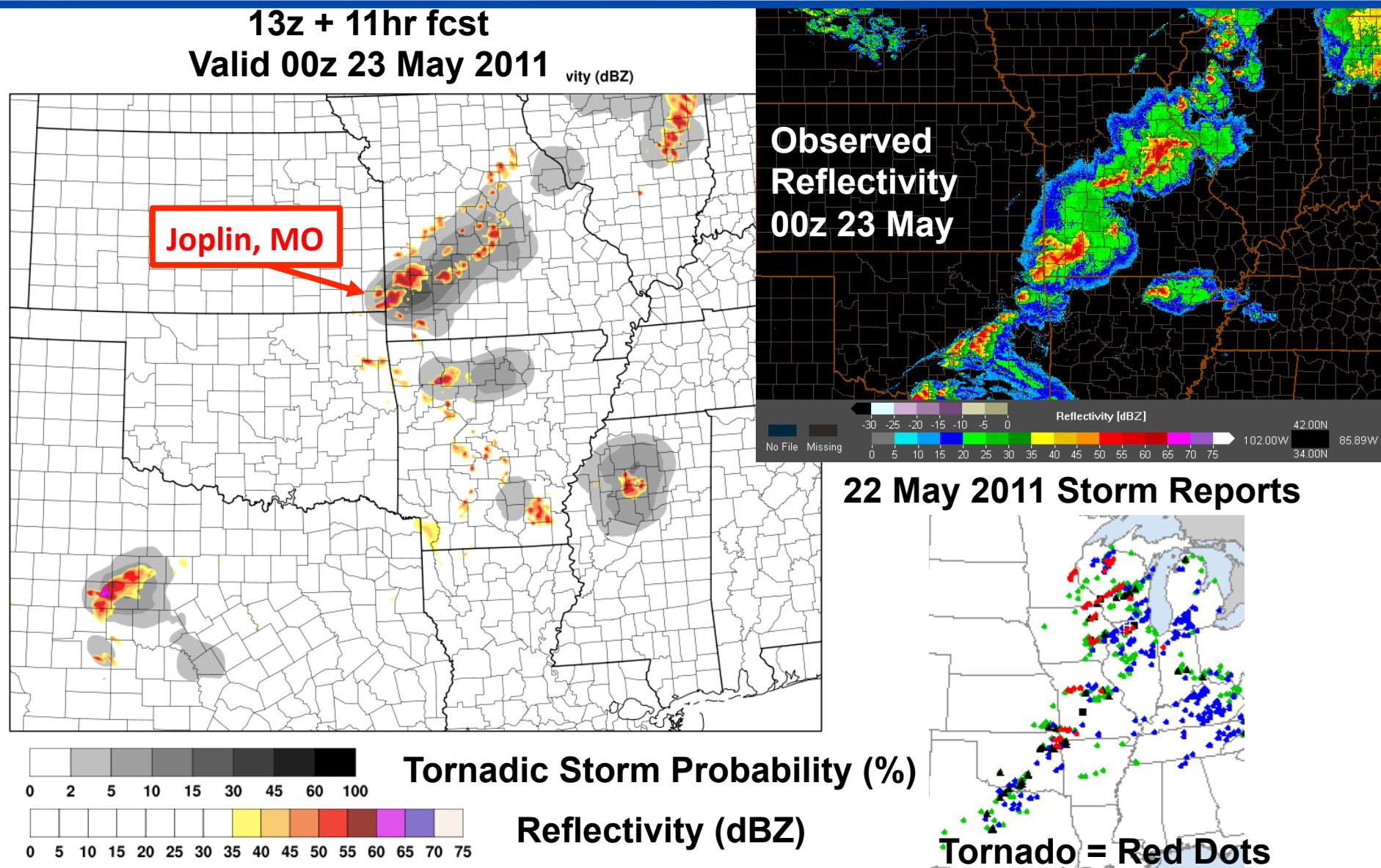


22 May 2011 Storm Reports

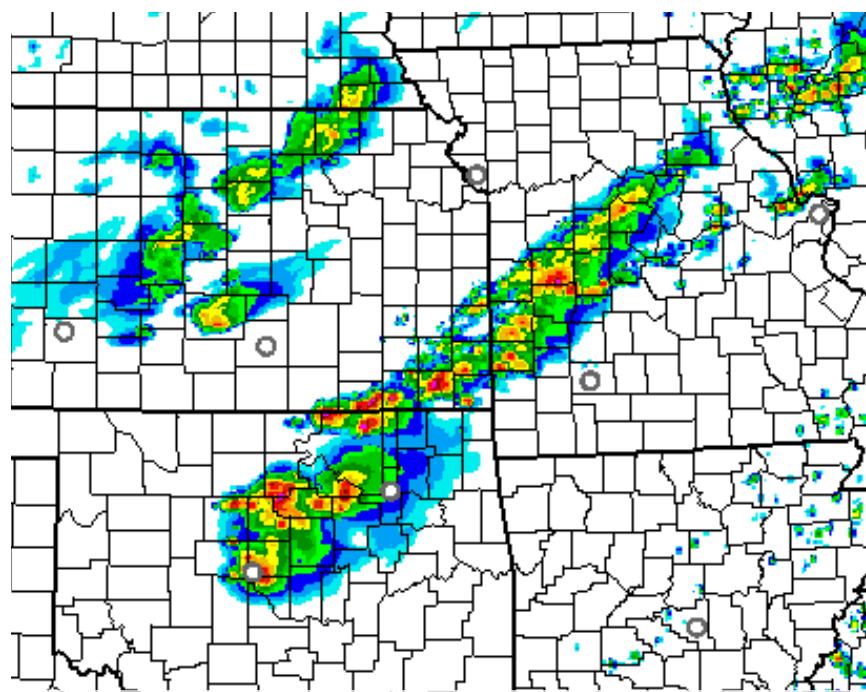




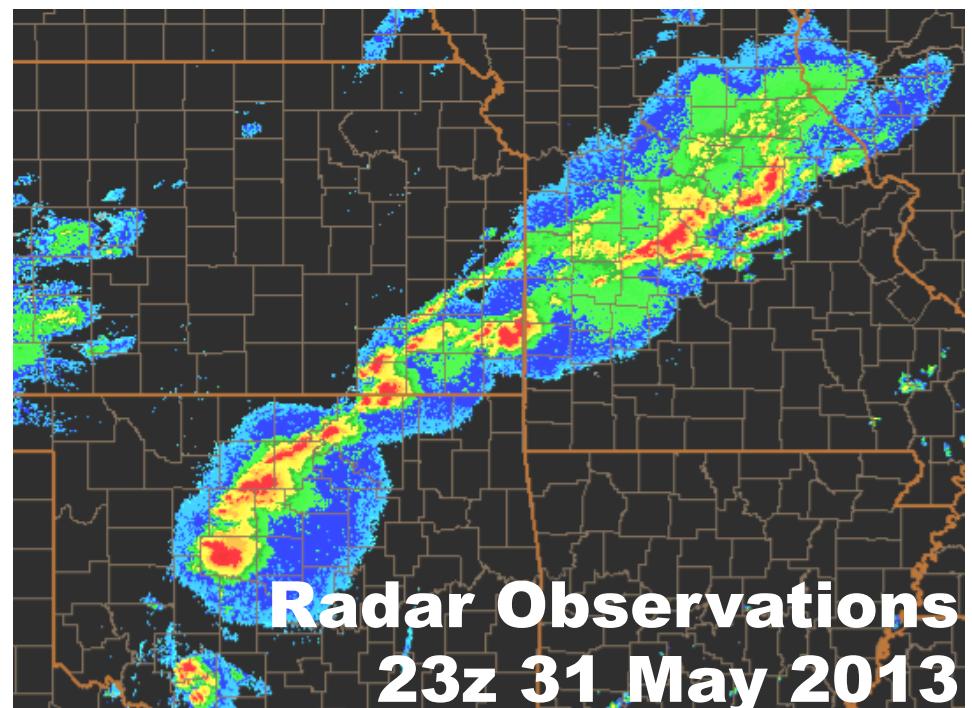
Example: 22 May 2011



31 May 2013 Oklahoma/Missouri tornado/flashflood event



**HRRR 10-h forecast
valid 23z 31 May**



**Radar Observations
23z 31 May 2013**



HRRR Real-Time Exper Products

	Background	Dimensionality	Updated
2012 HRRR model initialization	13-km RAP	3-D	Hourly
2013 HRRR model initialization	13-km RAP	3-D	Hourly
Rapidly Updating Analysis (RUA-HRRR)	3-km HRRR 1 hr fcst	3-D	Hourly
Real-Time Meso Analysis (RTMA-HRRR)	3-km HRRR 1 hr fcst	2-D	Hourly (15 min planned)
Time-Lagged HRRR (HCPF)	3-km HRRR Fcsts	2-D	Hourly

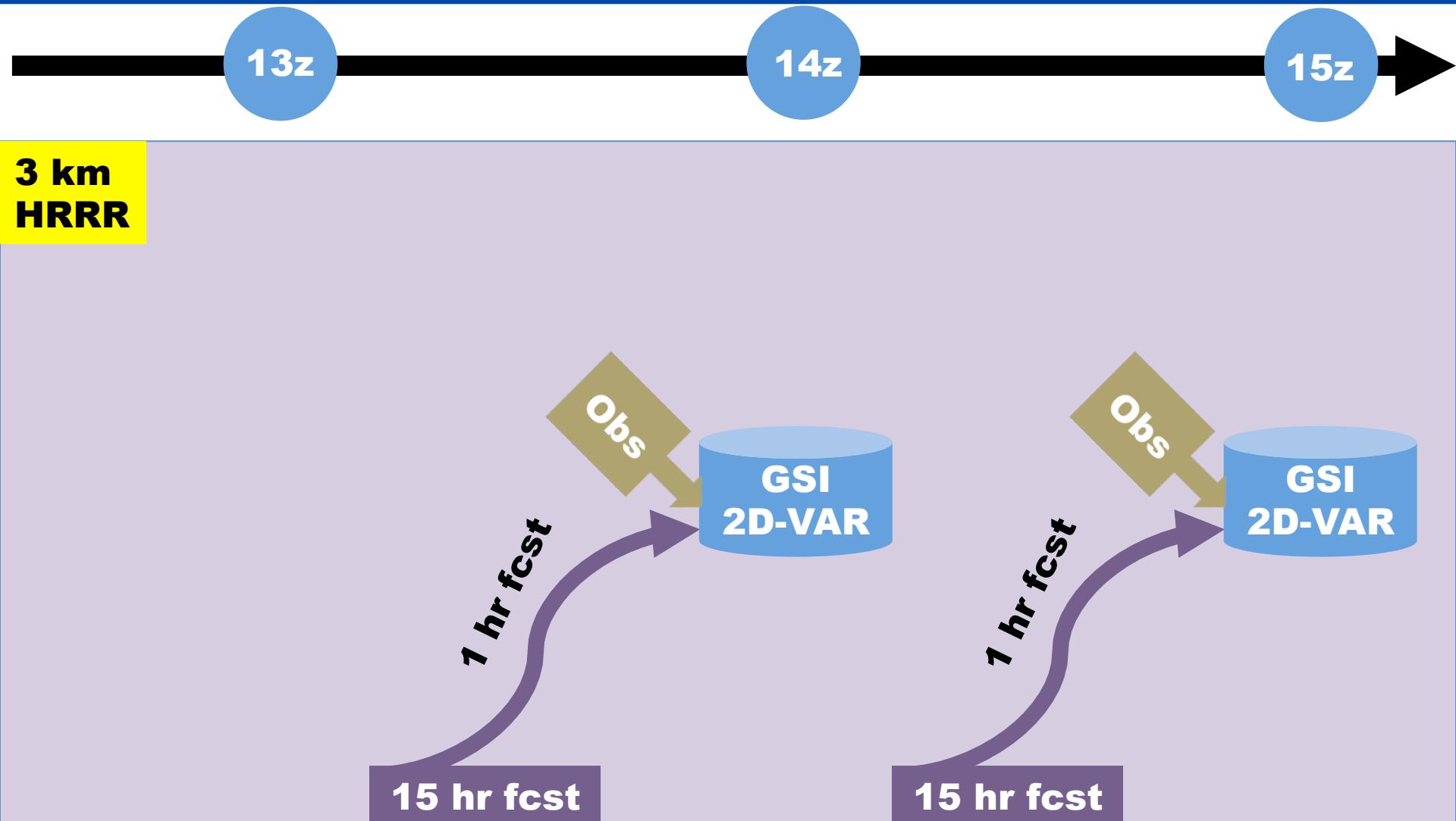


HRRR Real-Time Exper Products

	GSI Variational Analysis Grid	GSI Hydrometeor (HM) Analysis Grid	GSI Scale of Latent Heating	GSI Thompson-Retrieval Precip HM	GSI Retrieval Cloud HM	CPUs	Run Time
2013 RAP	Hybrid 27-km (2x coarser)	13-km (native grid)	13-km DFI	Always clear, Build snow columns when $T_{sfc} < 5^{\circ}\text{C}$, Build/scale rain/snow at max obs reflect level when $T_{sfc} > 5^{\circ}\text{C}$	Always clear, Build < 1.2 km AGL	96	6 min
2013 HRRR	12-km (4x coarser)	3-km (native grid)	13-km DFI, 3-km 60-min spin-up	Always clear, Build < 1.2 km AGL	120	9 min	
RUA-HRRR	N/A	3-km (native grid)	None	Full-column clear/build	Full-column clear/build	84	9 min
RTMA-HRRR	3-km (native grid)	N/A	None	N/A	N/A	60	9 min
Time-Lagged HRRR	45 - 90 km radius 2 hr window	N/A	None	N/A	N/A	1	40 min



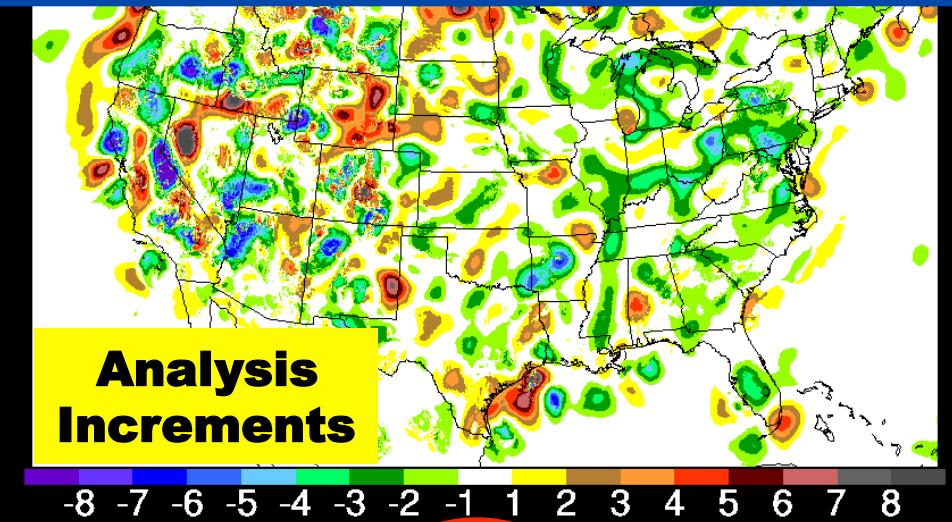
Hourly HRRR RTMA



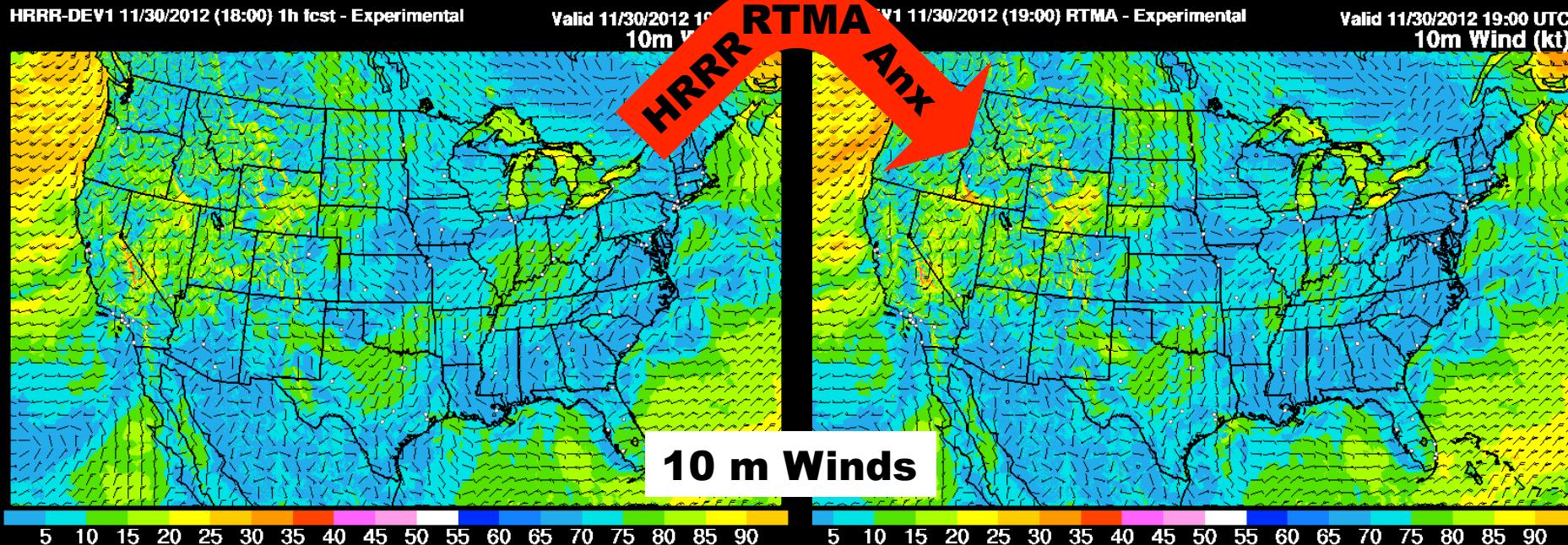


3-km HRRR RTMA

**1-hr HRRR Fcst
(Background)
Valid 19 UTC
30 Nov 2012**



**0-hr HRRR Anal
Valid 19 UTC
30 Nov 2012**





3-km RTMA w/ HRRR bkg

RMS error/fit vs. METAR/surface obs

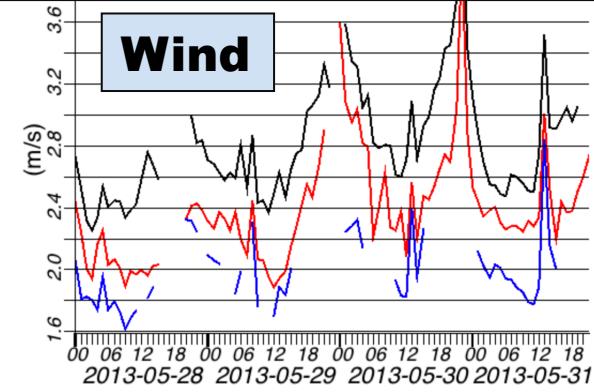
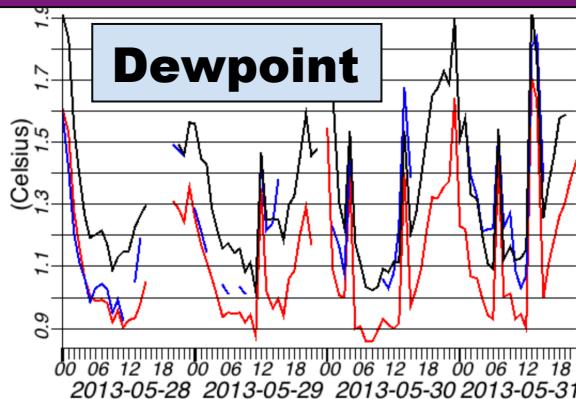
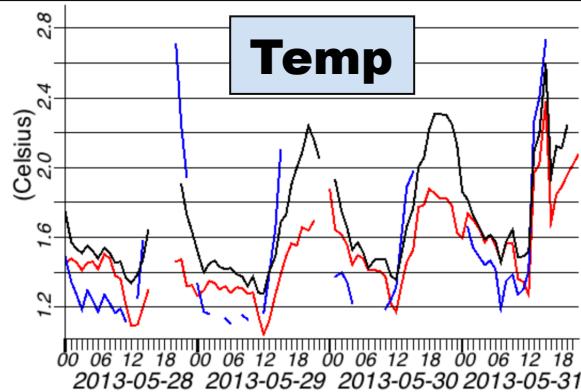
28 – 31 May 2013

RTMA-HRRR Anx

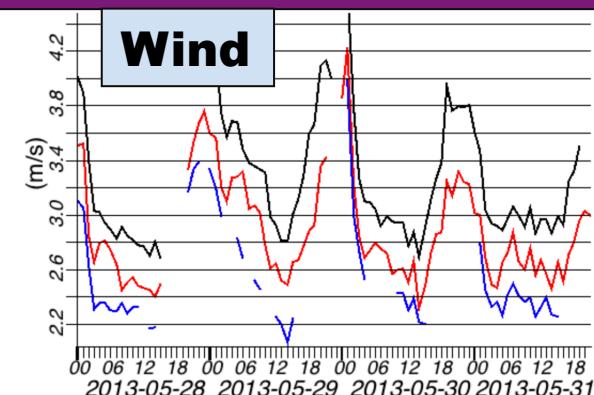
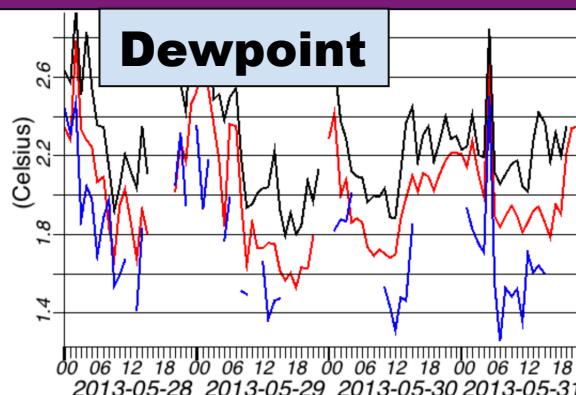
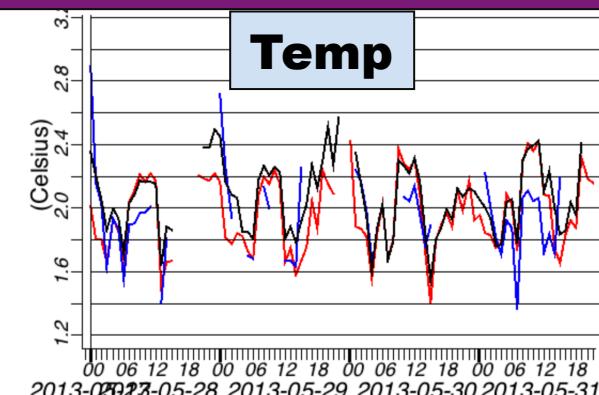
HRRR 1hr fcst

HRRR Anx

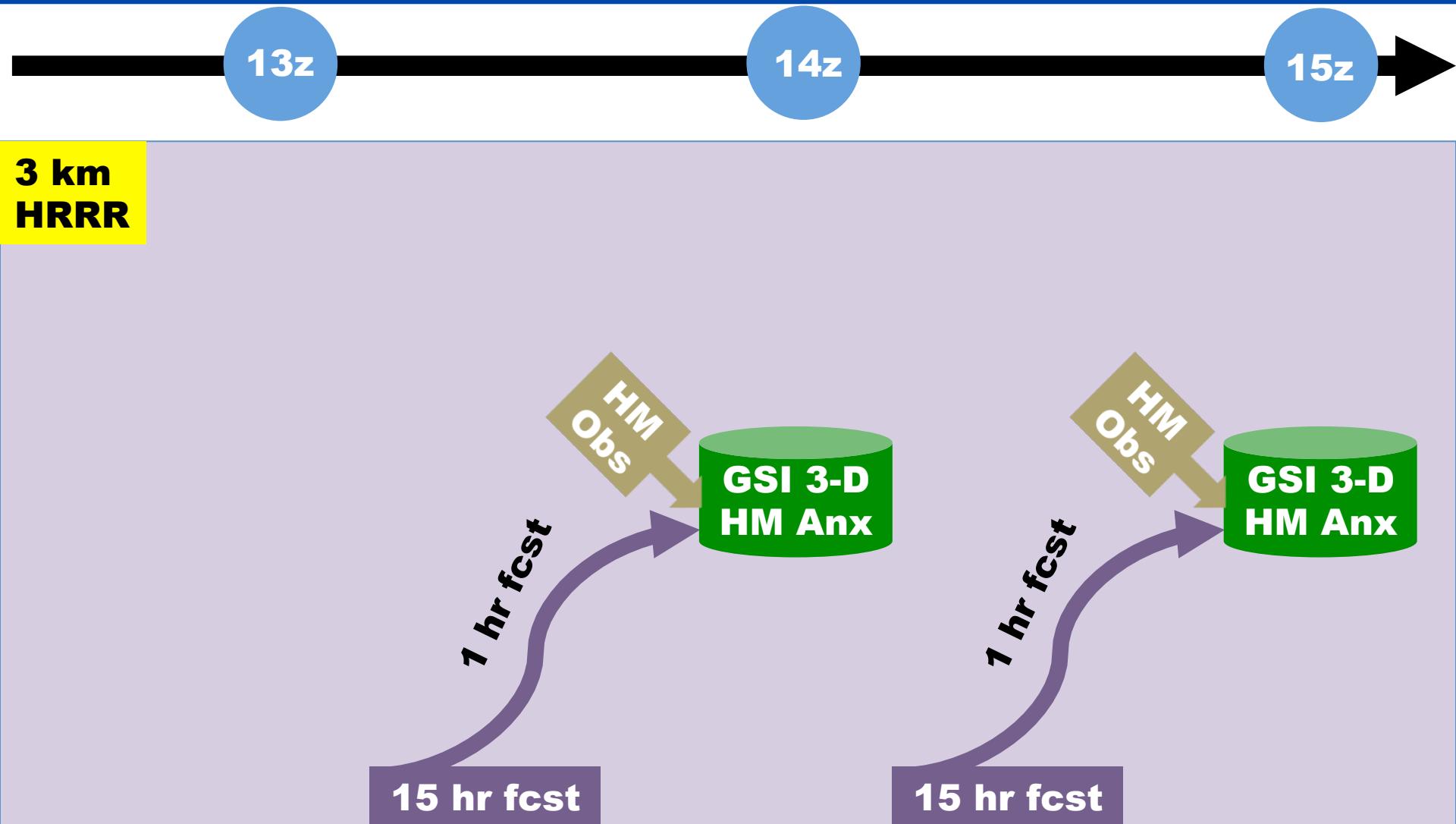
Eastern US



Western US



Hourly HRRR Rapidly Updating Anx





3-km HRRR RUA

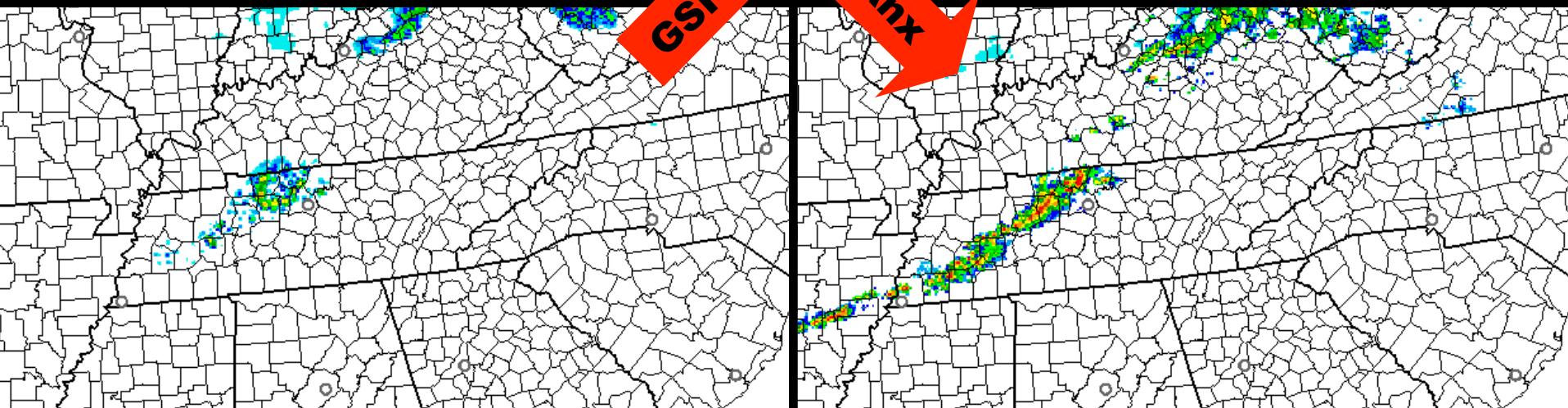
Rapidly
Updating
Analysis
(RUA)

Obs
22 UTC
03 Nov 2012



Species
Hydrometeors
From Radar
Observations

GSI Cloud Anx



1-hr HRRR Forecast (Background)
Valid 22 UTC
03 November 2012

0-hr HRRR Analysis (RUA)
Valid 22 UTC
03 November 2012



HRRR Transition to NCEP

- **Current – 1 computer running HRRR**
 - NOAA/ESRL – Boulder
 - Current reliability: 97% for last 12h months
(allowing up to 3h gaps)
- **2013-14 – 2 computers running HRRR – interim solution**
 - Boulder – computer 1
 - Fairmont, WV – computer 2
 - Expected reliability to increase further to 98.5-99% via coordination of downtimes for Boulder vs. Fairmont computers
- **Est. FY2014 – NCEP running RAPv2 (Q1) and HRRR (Q2)**
 - Effort underway to begin testing HRRR at NCEP
- Conclusion: *Interim HRRR computing for 2013 on 2 sites to provide “real-time experimental” HRRR from NOAA for NWS, FAA, DOE/energy users until HRRR impl @NCEP*